Herd management and the social role of herding at Neolithic Çatalhőyűk:

an investigation using oxygen isotope and dental microwear evidence in sheep.

Elizabeth Mary Henton

University College London

Institute of Archaeology

PhD.

2010

Funded by AHRC, NERC, UCL Graduate School and Institute of Archaeology, UCL.

I, Elizabeth Mary Henton, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Many Neolithic settlements in southwest Asia maintained economic dependence on domestic caprine herds over long periods. This thesis explores the success of sheep herding in one 1200 year-old Neolithic settlement – Çatalhöyük, Central Anatolia (7400 – 6200 cal. BC). The evidence from two datasets is used to expand knowledge of the seasonal management of domestic sheep herds and their food resources. Successful herding is measured in terms of being able to maintain good husbandry practices whilst meeting the needs of the settlement.

Samples of archaeological sheep's teeth from Çatalhöyük are used in two ways: sequential oxygen isotope values from a sheep's second mandibular molar give seasonality evidence during the first year of a sheep's life, and are used to establish the birth season and mobility patterns over the year. Dental microwear analysis of the same tooth's occlusal surface provides evidence of the dietary regime in the last few weeks of that sheep's life, and is used to distinguish the type and quality of diet before slaughter. Together, the data outline a life history for each sheep, and are used to reveal the pattern of herding control and food resource manipulation.

Çatalhöyük is within the habitat of wild sheep, where palaeoenvironmental modelling suggests that domestic herd management could have proceeded in the wider landscape with minimal niche construction. However settlement demands, both economic and social, might have prompted more convenient solutions, reliant on more extensive niche construction in a more limited local environment. The herders' ability, or commitment, to maintaining best husbandry practices is explored by bringing the ethology of sheep to an interpretation of how environmental possibilities might have been utilized.

Contents

List of figures

List of tables

Appendices

Acknowledgements

First, and foremost, I would like to thank my supervisor, Louise Martin, my secondary supervisor, Ken Thomas, and my subsidiary supervisor, Ingrid Mainland, for their guidance and patience over the last four years.

Secondly, I would like to thank the Çatalhöyük Research Project for allowing me to use their material in this research, and, in particular, Ian Hodder, Shahina Farid, Nerissa Russell, Kathy Twiss and Banu Aydınoğlugil for their support.

In central Anatolia, I am grateful to Naci Kayan and Mevlut Sivaş for collecting modern material and for all their information, and to Arzu Demirergi, Müge Ergun, and Melis Uzdurum for their help with interpretation. I thank Mihriban Özbaşaran and Füsun Ertuğ-Yaraş, of the Aşıklı Research Project, who helped to make modern collections possible, as did the British Institute of Archaeology in Ankara, Mehmet Ali Kaya and Kürşat Turgut of Selcuk University and Musa Çelik of the Bozdağ Wild Sheep Reserve.

In the UK, I am indebted to Wolfram Meier-Augenstein and Helen Kemp of the Scottish Crop Research Institute, Angela Lamb and Jane Evans of the NERC Isotope Geoscience Laboratory, and Page Chamberlain and Peter Blisniuk of Stanford University for the isotope analyses. At the Institute of Archaeology, I would like to thank Sandra Bond, Kevin Reeves and Ash Rennie for their technical support and Lisa Daniels for her administrative help. On a personal note, I thank everyone in 322B for their friendliness, Bronwen Evans for her Norfolk seaside retreat, and Joan Hodsdon for her dedicated proof reading.

This thesis is dedicated to the two Plikáti sheep who escaped from leafy-hay feeding experiments to graze on pasture.

INTRODUCTION

My interest is in ordinary working lives – the knowledge and skills underlying good practice, the work-environment, the day-to-day activities and the yearly round of tasks. I want to explore how workers balance good practice against demand for their products, and how their work is defined, perceived and valued within the community. As a zooarchaeologist working on the Neolithic of southwest Asia, the focus of my interest lies in the lives of early herders of domestic ungulates in mixed agricultural settlements, and in their ability to put their knowledge into practice.

Herding is a complicated business, requiring knowledge, skill and labour to raise, protect and feed viable herds, to regulate the off-take associated with product goals and to maintain suitable food resources. During the life-history of herd animals their food and protection requirements change, furthermore, their food resources alter seasonally and need careful conservation. Wild herd animals split into different herd parts in order to synchronise need with resource availability. Herders of domestic flocks, too, commonly keep pregnant ewes and lambs separately in breeding herds, targeting them to nutritious food and protection; the growing juveniles and barren females in the herd are often removed from these optimal conditions and are fallowed elsewhere on less nutritious food and with less herding protection. Where meat products are the consumer goal, certain parts of the fallow domestic herd are moved onto nutritious foods for fattening up in the weeks before their slaughter. Beck's (1991) book, 'Nomad, a year in the life of a Qashqa'i tribesman in Iran', is, *inter alia*, an account of near-constant herd splitting onto different pastures. These pastures become available with the seasons but access to them is a function of the skills and perceived status of the herders.

How may the working lives of Neolithic herders be approached? My thesis is two-fold;

firstly I argue that herders had at their disposal a body of knowledge and skills passed on to them by antecedent and coeval societies, but their final choice would have been highly contingent on socio-ritual and environmental factors pertaining to their settlement and its landscape. Secondly, in the construction of the niche of domestication, I argue that herders would have brought their skills and knowledge into play as they sought to maintain herd security and meet product goals through providing the best possible conditions of protection and feeding needed at different stages in the life of the herd animals. These optimal conditions might be modelled by analogy to biological evidence gleaned from published ethological research on wild sheep, agricultural research on domestic sheep and ethnographic information pertaining to herding.

In both strands of the thesis I propose that it is the matches and mismatches, between a notional suite of possible optimal practices and those actually in place, which provide the interpretive basis for approaching the tensions operating on herding decisions. These might include environmental pressures and opportunities, the relationship with crop cultivation, changing animal–human relations, the degree of specialism and status in the community, and the interface between regional and settlement identity.

Both aspects of the thesis demand an approach that uses highly contextual information, contingent on the environment and society of one settlement. I have chosen Çatalhöyük as my case-study as it is situated on the chronological and spatial fringes of the later Neolithic of southwest Asia, where there is ample evidence of a long history of domestic herding, commonly alongside domestic arable farming forming mixed agricultural settlements. Çatalhöyük's large zooarchaeological assemblage offers a sample size suitable for interpretation of its occupants' herding practices.

The thesis requires two sets of evidence. The body of knowledge that might be available to Çatalhöyük herders may be gathered through literature review of relevant sites in southwest

Asia, and compared to published evidence and interpretation of Çatalhöyük's herding practices. However, the management of herds and their resources at Çatalhöyük cannot fully be elucidated through standard zooarchaeological analyses, particularly as the on-site animal remains probably derive only from herd parts earmarked for slaughter. It is necessary to move beyond the product-goal economy and to investigate the means of production: that is, the herded animals throughout their lives, and also their food resources.

In order to approach the seasonal and spatial distribution of animals, highly contextual evidence is required that might elucidate the environment in which individual animals were raised at different points in their lives. Published interpretation of the Çatalhöyük palaeoenvironment might provide the basis for modelling the seasonal and spatial distribution of pasture and fodder resources that are nutritionally optimal at different point in the life histories of the herd animals.

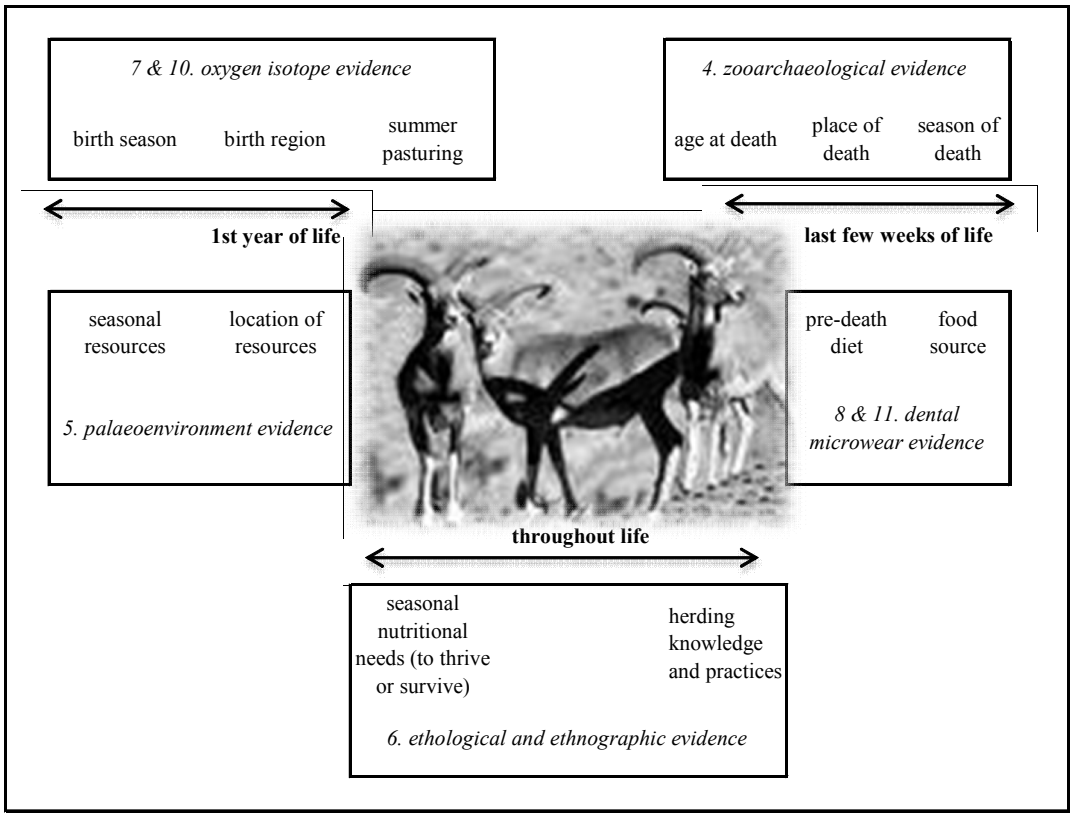


Figure 0.1
The evidence necessary to approach the herding conditions experienced by Çatalhöyük sheep throughout their lives.
Numbers refer to relevant chapters in the thesis

My methodological approach combines the evidence from two datasets, oxygen isotopes and dental microwear, taken from the tooth enamel of archaeological and modern sheep. Both datasets have a resolution of a few weeks, where, as will be explained, oxygen isotope evidence can provide detail of the seasonality of sheep breeding and the movement of fallowed sheep during their first year, and dental microwear evidence indicates the diet, just before death, of sheep that might have been destined for slaughter (*Figure 0.1*). I construct a locally-relevant modern comparator that allows the evidence to be modelled, in order to elucidate the articulation of herding at Catalhoyuk with the environment, the settlement and with crop cultivation.

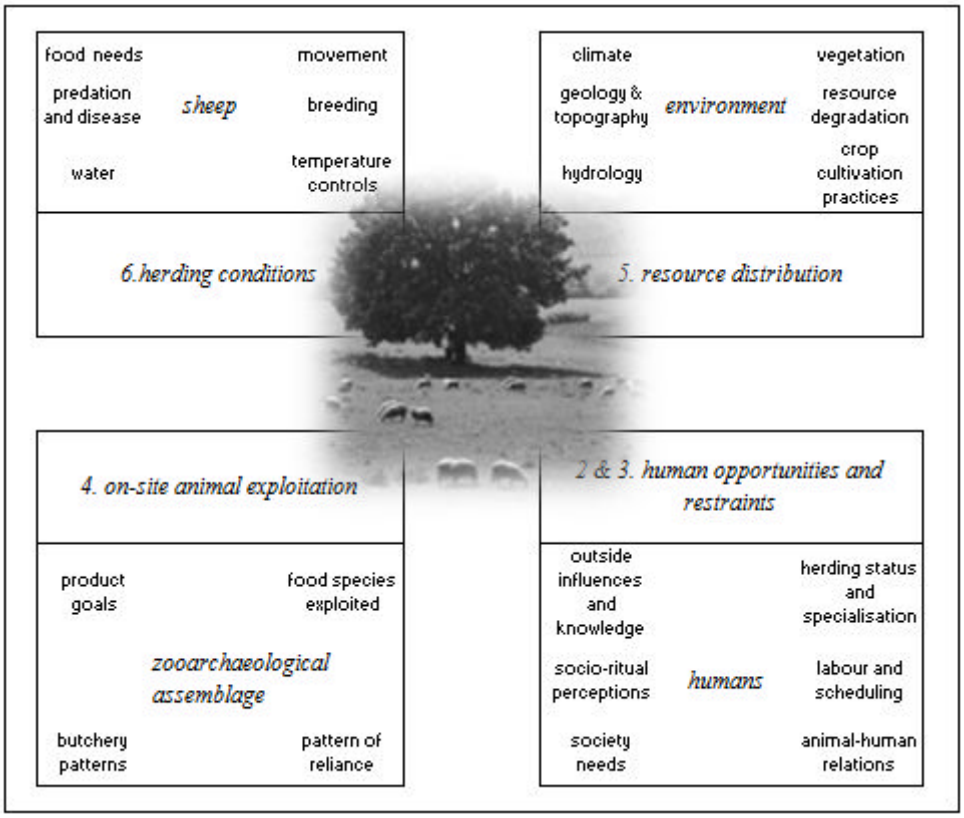


Figure 0.2
The evidence needed to understand how the landscape was used in order to meet needs of sheep and herders.
Numbers refer to relevant chapter in the thesis

As the thesis unfolds, the contextual resolution becomes greater as it moves from the broader regional context of herding, to the material and cultural context of the settlement, and then on to a more focused assessment of the settlement's economy and the palaeoenvironment

(*Figure 0.2*). Increasing the resolution further, the thesis confines itself to sheep and the research focuses on samples of single teeth from individual archaeological sheep.

In analysis and interpretation of the results the thesis broadens out again. The evidence from each tooth is interpreted, via a modern comparator, in terms of environmental conditions, and likely seasonal locations in the palaeoenvironment. Results then lead to the interpretation of possible herding practices at defined stages during the settlement. Drawing in the information from Çatalhöyük's material culture, the thesis returns to considering the herders, rather than their sheep, in terms of what the interpreted herding practices might reveal about their integration, status and specialism. At this point, chronological and spatial patterning is identified and discussed. Finally, returning to the regional scale, the interpreted pattern of herding practices is compared to others in southwest Asia and the contribution that the thesis might make to zooarchaeological approaches to the Neolithic of southwest Asia is assessed.

The thesis, illustrated in *Figures 0.1* and *0.2*, is structured as follows. *Chapter 1* introduces the framework to the research; it is here that the aims are stated, and the choice of context, approach, methods and theoretical basis argued. The research is put in its regional context in *Chapter 2* through review of herding practices in the Neolithic of southwest Asia, and into its settlement context in *Chapter 3*, where the case-study, Çatalhöyük, is introduced, and the evidence and interpretation of its material culture discussed. *Chapter 4* outlines the zooarchaeological evidence for herding and the current interpretation of the Çatalhöyük economy, and makes brief comparison to regional practices.

Chapter 5 takes an ecological approach in reconstructing the published palaeoenvironmental evidence in preparation for a modelled sheep pasturing landscape at Çatalhöyük. This chapter includes the anthropogenic environment of cultivation and land degradation. In *Chapter 6,* the biological and ethnographic evidence of sheep and sheep herding is reviewed,

and is central in establishing predictive models that assume that herd splitting would have been necessary for successful sheep herding in the Neolithic. Firstly, the spatial and temporal distribution of Çatalhöyük landscape resources are defined in terms of the optimal needs of sheep; secondly, the life-cycle of male and female sheep in herds focused on meat production are constructed; and thirdly, the seasonal feeding and protection requirements of sheep in breeding, fallow and slaughter herds are modelled.

New data generated as part of this research makes up the rest of the thesis. In *Chapters 7* and *8* respectively, the oxygen isotope and dental microwear methodologies are introduced and the contribution and limitations of their empirical datasets assessed. Late in the thesis, it is finally possible, in *Chapter 9*, to bring together the threads of the research design, including the construction of a modern baseline suitable for predictive modelling of breeding seasons, herd movement strategies and diets before death. In this chapter, the limitations and issues in devising a sampling strategy are discussed before a suitable sample set for chronological and spatial analysis of the archaeological data is selected and analysed.

Chapters 10 and *11* separately discuss the results of the oxygen isotope and dental microwear analyses within the modelled modern comparator and known biological evidence of sheep behaviour, before *Chapter 12* provides a more interpretive synthesis. It first draws together both sets of results, understood within the published palaeoenvironmental and zooarchaeological evidence and, by playing off different evidential strands against each other, proposes an outline of herding practices at Çatalhöyük. Assessment of the spatial and chronological evidence highlights possible changes in herding practice. These changes are compared to the chronological sequence in the Çatalhöyük material culture and to herding practices in the wider region of southwest Asia in order to infer possible influences and connections.

CHAPTER 1. RESEARCH FRAMEWORK: AIMS, CONTEXT, APPROACHES, METHODS AND THEORY

1.1. Research aims

This thesis presents evidence from datasets selected to expand knowledge of the seasonal management of domestic sheep herds, and their food resources, in the landscape of Çatalhöyük: a later Neolithic settlement in central Anatolia, southwest Asia. The aim is to provide highly contextual detail for individual sheep, and then to understand variation as a function of three factors; firstly, how optimally each sheep was raised; secondly, how herders balanced good sheep husbandry against the needs of the community and the constraints of the environment. Thirdly, how herding success related to the degree of integration between herding and arable farming, and to the perception of herding within the community.

1.2. Research context

The economic basis to the Neolithic revolution – change in the cultural control of the food economy – took millennia to consolidate and to manifest itself unequivocally in the archaeological record. The cultivation of plants begun *c.* 9500 cal. BC, 1000 years before their domestication can be identified morphologically (Wilcox *et al.* 2008). Similarly, 2000 years probably elapsed between the first attempts to take cultural control of sheep and goats and the genetic manifestation of that control (Zeder 2009, 37). Not until the end of the 7th millennium BC can the consolidated Neolithic package of domesticates be found in most settlements across southwest Asia (*Chapter 2*).

The time-depth and complexity in the establishment of Neolithic culture encourages a shift in research focus, from one that attempted to pinpoint threshold moments or centres, to one

that attempts to document the long unfolding process (Zeder 2009, 38). Such documentation might usefully include detailed evidence from one settlement during a defined time period. It is towards the end of the Neolithic, in one large settlement on the geographical fringes of one centre of Neolithic revolution that this thesis situates itself.

Çatalhöyük occupies a chronological and spatial place in the Neolithic of southwest Asia that makes it an ideal case study for this thesis. The settlement is on the Konya Plain of central Anatolia, on the fringes of the Fertile Crescent (*Figure 2.1*); the locus of the main developments in the Neolithic of southwest Asia (*Chapter 2*). Çatalhöyük East was first settled *c.* 7400 cal. BC and was occupied until *c.* 6200 cal. BC (Cessford 2005a) before re-locating to the twin mound, Çatalhöyük West, at the start of the Chalcolithic. Its architecture and tool kits, its domestic and ritual evidence, resonate with other settlements throughout southwest Asia, and indicate that Çatalhöyük East was part of a complex social interaction over a wide region (*Chapter 3*).

From the start of Çatalhöyük East's (hereafter Çatalhöyük) settlement, domestic plants were cultivated and domestic sheep and goat herded (Fairbairn *et al.* 2005; Russell & Martin 2005), and it is probable that the earliest farming practices at Çatalhöyük had ancestral roots elsewhere (*Chapter 4*). At this time, late in the Neolithic, the evidence points to there already being a long history of cultural control and domestication of plants and animals throughout the Fertile Crescent (Legge 1996, 238). Çatalhöyük practices echo those in some antecedent and coeval settlements in the wider region, but not others (*Chapters 2, 3* and *4*). Inter-settlement and inter-regional differences in the exploitation and product goals of different plant and animal species demand, at least in part, explanation contingent on the social and environmental history of the settlement.

The longevity of the Çatalhöyük settlement allows over 1200 years of successful herding practices to be explored. There is minimal evidence of social stratification or specialisation

at Çatalhöyük; indeed, the evidence is of reiterative, egalitarian practices (Hodder2006) (*Chapter 3*). Nevertheless, there are later changes in the material culture and architecture which coincide with the early management and domestication of cattle (Twiss *et al.* 2010) (*Chapter 4*). Such developments echoed those in many newly established settlements in southwest Asia (Simmons 2000), and might suggest that herding played a role in the emerging changes in social organisation.

Çatalhöyük has been extensively excavated, and has a large corpus of published data and interpretation, all adding to the suitability of this settlement as a case study. Yet herding would have largely taken place off-site, where evidence is less easy to gather. The seasonal management of herds would have been intricately tied to the management of graze and fodder resources, in an environment where seasonal flooding might have led to competition between arable farming and pasturing (Roberts & Rosen 2009), or to tightly scheduled co-operation (Bogaard 2005) (*Chapter 5*). Published analyses of the zooarchaeological assemblage (Russell & Martin 2005; Twiss *et al.* 2010) and the identification and analysis of on-site herd animal management and diet (Fairbairn *et al.* 2005; Matthews 2005) provide the backbone to understanding the economy and product goals (*Chapters 4* and *5*). However, additional data are needed to discriminate foddering and grazing strategies, and to elucidate the seasonal control of breeding, moving and grazing location throughout the lives of the herd animals.

In this thesis, the research approaches taken, the research methods used, and the theoretical structure established, are all largely dictated by the aim. As it unfolds, the thesis follows more than one avenue of enquiry and interrogates more than one dataset; the theoretical framework integrates these threads and structures the underlying thesis.

The purpose of the rest of this chapter is to review and critique approaches, methods and theoretical paradigms relevant to caprine herding in early settled agricultural societies

(*Sections 1.3, 1.5* and *1.7*) as a basis for identifying and selecting those most appropriate to this thesis (*Sections 1.4, 1.6* and *1.8*). It is not the purpose of this chapter to go beyond a discussion of approaches, methods and theory; in *Chapter 2*, herding practices in southwest Asia are reviewed, and it is here that more detailed evidence is given.

1.3. Research approaches

1.3.1. Introduction

Verhoeven (2004, 180) has proposed that approaches fall into three broad categories: environmental, social and cognitive. Even if these can seem imposed, they make a useful starting point for discussion.

Environmental approaches focus on aspects of palaeoenvironmental reconstruction, and emphasise the role of the material conditions in determining human action and adaptation. Archaeologists using environmental approaches have gathered valuable data that contribute to a chronological and spatial understanding of the Neolithic palaeoenvironmental sequence; its climate, its flora and its fauna (Wasse 2007, 52). However, environmental approaches run the risk of being deterministic, and overlooking human agency or belief.

Social approaches attempt to answer why humans responded, or adapted, as they did to the opportunities or stresses of their material world. Archaeologists using social approaches to Neolithic herding practices have considered, for example, how risk was managed (Halstead 1989; Redding 1984) and how societies responded to increasing population pressures (Kuijt 2000; Rollefson & Köhler-Rollefson 1989). Nevertheless, social approaches, despite allowing human agency, tend to model human responses as essentially adaptive (Verhoeven 2004, 180).

Cognitive approaches take changes in human thought as prerequisite to effecting changes in

practice. Archaeologists using cognitive approaches to domestication have, for example, interpreted highly contextual architectural or material culture datasets as signifiers and organisers of increasingly domesticated mindsets (Cauvin 2000; Hodder 1990). Cognitive approaches, however, can be too dependent on western constructs such as a nature–culture dichotomy (Ingold 1996).

As evidence accumulated, and as methodologies became more refined, approaches were less often unicausal and more frequently modelled multiple causes, or constructed multiple scales of temporal and spatial development (Verhoeven 2004), and it might be expected that in this thesis the most appropriate approach will have many strands. This section continues by posing a series of questions of interest to this thesis. Research approaches used to address these questions are discussed, and their suitability for this research assessed.

1.3.2. Did settlements have domestic animals?

Meadow (1989) introduced a suite of criteria to help identify domesticated herd animals in archaeological bone assemblages. These criteria are most successful in identifying biologically domesticated animals in settlements outside wild progenitor habitats (Hole *et al.* 1969; Wasse 1997), and late in the Neolithic sequence (Clason 1979–1980; Russell & Martin 2005).

As the search for the centres of earliest domestications moved into areas where wild progenitors lived (Braidwood & Howe 1960; Hongo & Meadow 1998; Legge & Rowley-Conwy 2000; Rosenberg *et al.* 1995), research turned to the process leading to domestication. Herd-profile modelling, using data from zooarchaeological assemblages, was introduced to elucidate the early management of animals before the biological markers of domestication manifested themselves (Buitenhuis 1997; Hesse 1984; Horwitz 1989; Martin *et al.* 2002).

The cultural control of animals is now considered to be the most relevant to the study of the Neolithic (Wasse 2007, 51) as the moment of biological domestication would have been an unmarked accumulation of practices. The process of cultural control is considered by some to be unilinear; Horwitz (1989) identifies four stages that might be approached methodologically. Hongo and Meadow (1998, 77), however, argue for a more flexible continuum of control which might increase, or decrease again, over time.

In Çatalhöyük, some herd animals are identified by biological markers as domestic, some are identified by herd profiles as being under early stages of cultural control, and some have no evidence of being managed (*Chapter 4*). In this fluid situation, it is likely that the management of herds and their food resources would have been frequently adjusted, in order to accommodate changes in the economy. It might be profitable to consider approaches that focus on seasonal herd and resource management.

1.3.3. How was the composition of domestic herds determined?

The composition of herds is likely to have been one of the most important factors in scheduling their food resources at Çatalhöyük. Payne (1973) modelled herd profiles that might distinguish between death assemblages associated with herds optimised for meat, milk or wool production. A meat herd, for example, would be composed of breeding females and young lambs, male and female lambs and juveniles growing to maturity, and young males in prime meat-weight condition earmarked for slaughter; it is this last cohort of prime males that dominates the on-site zooarchaeological assemblage. Halstead (1996) draws on ethnographic information to argue that subsistence strategies, where more than one product is desired, would have been more likely during the Neolithic. For example ewes might have been lightly milked whilst keeping male lambs alive until their maximum meat weight was reached.

Herd composition is not only designed to maximise products. Redding (1984) used optimal foraging theory to show that herd security is dependent on certain parameters of herd-composition and herd-size; it would have been a prime concern of early herders, including those attempting to establish viable herds of new domesticates in the later Neolithic (Saña i Seguí 2000). Halstead (1989) also models herd security to show how it would have incorporated a normal surplus, used to manage risk against the vagaries of the climate and the epidemic effects of some diseases. Stein (1989) models resource diversification as another means of managing risk.

The underlying need for herd security establishes an important insight; good husbandry would have been essential if herders were to have provided the community with animal products. It might have included careful targeting of the best resources to breeding ewes and lambs in order to boost reproduction success, whilst still ensuring that animals for slaughter carried maximum body weight. The insight suggests a basis for modelled resource scheduling and herd movement in this thesis.

1.3.4. Was there an increasing reliance on domestic animals?

In their regional overviews of the evidence from southwest Asia, both Legge (1996) and Peters *et al.* (2005) show there was an increasing reliance on domestic products as the Neolithic progressed; both propose that domestic sheep exploitation, in particular, marked an unequivocal point in this process within and outside sheep native habitats (*Chapter 2*). Extensive research has been dedicated to elucidating this pattern.

Hofmann (1989) uses behavioural ecology to model how the behaviour and physiology of sheep make them the most useful and productive herd animals, even as introductions to settlements outside their native habitat. Moore *et al.*'s (2000) study of the economy of Abu Hureyra shows that mixed agricultural economies were robust enough to allow increasing reliance on domestic herds (even if they were primarily raised as 'walking larders' (Flannery

1969), rather than for more productive milk products). In support, Halstead and O'Shea (1989) and Stein (1989) argue that mixed economies would enable flexible responses if necessary.

Hunted food continued to play a part in settlement economies, and was not fully replaced by the increasing reliance on domestic products. Flexible reliance on hunted resources has been modelled by some researchers to act as a buffer against herd failure (Legge 1996; Saña i Seguí 2000; Saña i Seguí & Helmer 1999), whereas others suggest that continued hunting was indicative of a conservative tradition (Hodder 1990; Ingold 1994).

One line of enquiry approaches increased herd-animal reliance as a marker of intensification; that is, the increasing returns in productive capacity for the same initial outlay. Intensification models tend to use a broad regional and temporal scale, and to assume unilinear trajectories, where societies were either pushed by pressures or pulled by opportunities into intensification (Zeder 2007, 113). A change from meat to milk production is considered the most likely way in which caprine exploitation intensified (Garrard *et al.* 1996), but evidence for this is elusive; attempts to refine the zooarchaeological modelling of herd profiles (*Section 1.5*) in order to identify milk introduction continue to dominate approaches.

Improved access to arable by-products for herd food resources, changing landscape use from hunting to pasturing territory, or greater efficiencies in labour scheduling might facilitate increasing reliance on particular herd animals without the need to change product goals (Monahan 2000). One approach to elucidating increasing reliance on caprines in the Neolithic of southwest Asia studies changes in herd foddering practices (e.g. Lösch *et al.* 2005; Pearson *et al*. 2007).

Despite long-term, regional trends, variety can be seen between settlement food economies (Hesse 1984; Peters *et al.* 2005; Rosenberg *et al.* 1995), some of which were coeval, or in identical, neighbouring environments to Çatalhöyük (Baird 2008; Buitenhuis 1997; Horwitz 1988). Peters *et al.* (2005) argue that it is more useful to examine site-based evidence of changing resource dependence and to interpret each site functionally within the context of its whole economy; this approach, they argue, can accommodate flexibility and non-linear trajectories. This view is echoed by Rowley-Conwy (2000, 131); '… a combination of tactics and historical contingency provides a better perspective on early agriculture than does a picture of gradually increasing intensification …'

In settlements such as Çatalhöyük, where sheep herding dominated the economy, and where the evidence for milk exploitation is lacking (*Chapter 4*), research approaches that investigate the historically and environmentally contingent evidence for the management of herds and their resources might usefully contribute to an understanding of the settlement's reliance on domestic products.

1.3.5. Did herding contribute to the decline or collapse of settlements?

Towards the end of the 8th millennium cal. BC many settlements in the south Levant collapsed (Kuijt 2000, 94), although the oasis settlement of 'Ain Ghazal continued with a much reduced occupation (Rollefson & Köhler-Rollefson 1993); in the north Levant, settlement collapse was less widespread (Akkermans & Schwartz 2003, 112). Settlement collapse has provoked a number of approaches that ask why it happened, how settlements responded, and why some settlements continued to be successful.

Several authors invoke climate change as a trigger to settlement collapse (Bar-Yosef 2001, 27; Bar-Yosef & Belfer-Cohen 1989; Nissen 1993; Simmons 1997, 309), although reconciliation of on-site and off-site dating (Baird 1997; Köhler-Rollefson 1988; Rollefson & Kohler Rollefson 1989, 84) shows that major periods of climate change did not correlate

with late 8th millennium cal. BC settlement collapse. In addition, climate change cannot account for the success of some settlements, especially those in marginal environments (Rollefson & Köhler-Rollefson 1989).

Kuijt (2000) considers the likely increase in disease and social crowding stress resulting from rapidly increasing populations; he argues that socio-ritual mechanisms that might cement society were weak in the south Levant, whereas in the north Levant they were more powerful and able to maintain social cohesion for longer. Halstead (1989) proposes that wealth displays, based on unused normal surplus, might have become unevenly distributed, resulting in social stratification that required new settlement and house patterns.

The case study of the late 8th millennium cal. BC in the south Levant, and 'Ain Ghazal in particular, raises interesting questions for current research. Debate continues as to whether collapse of this 'mega-site' was caused by land degradation arising from occupation longevity (Rollefson & Köhler-Rollefson 1989), overexploitation of wild and domestic food resources, land clearance or pasture overgrazing (Köhler-Rollefson 1988; 1992; Köhler-Rollefson & Rollefson 1990). Vegetation reconstruction (Hillman 1996) suggests that the rolling plains of the north Levant could have been more resilient to such pressures than the more rugged topographies of the south Levant (Peters *et al.* 2005).

How then did populations respond to site abandonment? Regional settlement patterns show that the abandonments in the south Levant were followed by the emergence of dispersed settlement patterns. New villages on the Levantine coast, for example, were reliant on arable farming and fishing rather than domestic caprine herds (Galili *et al.* 1993), and at 'Ain Ghazal, too, where a smaller settlement continued, caprine herds were also greatly reduced (*Chapter 2*). Early economic models of carrying capacity around 'Ain Ghazal suggested that goat herding would have needed to have moved further from the settlement over time (Köhler-Rollefson & Rollefson 1990). However, Campbell (2010) questions this assessment;

she models new data to show that the carrying capacity of the land might easily have accommodated adequate extensive agricultural systems and large caprine herds, and that Neolithic arable technologies, now described as conservation-based, would not have had a negative impact on the environment.

The evidence of settlement collapse stimulated a controversial explanation: societies had fissioned into settled arable farmers and nomadic pastoralists who were now raising herds for milk production. Certainly, risk-management models based on ethnographic information include increasing mobility as an effective solution (Halstead 1989). However, economic modelling suggests that meat herds would have made nomadic life impossible as they are four times less productive than milk herds (Russell 1988, 159), and methodological approaches have not revealed evidence of milk herding optimisation at this time (Halstead 1996; Sherratt 1981, 1983) despite earlier indications of less optimal milking in the north Levant (Helmer *et al.* 2007).

Research that investigates the movement of herds and the seasonal provision of their food resources in a long-lived settlement, such as Çatalhöyük, might usefully offer direct evidence of some of the measures that might have been taken to maintain successful herding practices in a mixed agricultural community.

1.3.6. How did herding make use of resources in the landscape?

Environmental reconstruction can model seasonal resources in ancient landscapes (Asouti 2005; Hillman 1996), but pollen gives coarse resolution, and on-site evidence gives partial vegetation data (Roberts 2002) biased by human choice (Fairbairn *et al.* 2005). Research on Neolithic crop cultivation systems (Bogaard 2005; Halstead 2006; Sherratt 1981, 1983) has provided influential models of settlement landscape use. These models include, but cannot identify the articulation of cultivation with herding and have become central in modelling herd deployment (Halstead 2006).

Bogaard (2005) has pioneered the idea of intensive 'garden farming', modelled as small-scale subsistence close to the settlement, and reliant on a high-cost labour schedule. This model includes a functional relationship with herders, where small herds are kept close by: available to manure plots whilst feeding on stubble and fallow weeds. Extensive agriculture is modelled as operating less intensively on a large scale with little crop fertilisation. In this system large herds are not needed for their manure and are herded further away from the settlement by specialist pastoralists living in occasionally, seasonally or permanently fissioned societies (Bogaard 2005). Where environmental reconstruction shows that agricultural land is not limited by topography or woodland encroachment (Chang & Koster 1986, 102; Halstead 2006, 45, 60),there is an additional model of outfields, at least for fallow herds during the crop growing season (Raish 1992).

In these models, the feeding ethology of animals has not been discussed, and evidence of herd animals close to the settlement cannot easily differentiate between year-round herding close by and seasonal activities such as foddering, birthing or slaughter (Mainland & Halstead 2002; Matthews 2005; Richards *et al.* 2003).

Research that investigates the detail of herd management, including the seasonal scheduling of breeding, the dietary regime of pre-slaughter animals and the annual grazing arrangements for non-breeding ewes and growing lambs and juveniles, might offer preliminary evidence of how herding could have articulated with crop cultivation in the wider landscape of a settlement such as Çatalhöyük.

1.3.7. What part does herding play in social organisation?

The evidence for domestic sheep herds in the Neolithic of southwest Asia is largely their bone and teeth remains found in middens. This is in marked contrast to the wealth of evidence of wild animals in ritual contexts (Hodder 2006), and it is tempting to relegate

domestic herding to a separate economic sphere. Indeed, Cauvin (2000) and Hodder (1990) argue that the domestication of plants and animals was an inadvertent process that followed the domestication of the mind. However, a separation of the social from the economic can be a useful device in modelling data, but is unhelpful when considering the experience of Neolithic people.

> One of the great mistakes of recent anthropology … has been to insist upon a separation between the domain of technical and social activity, a separation that has blinded us to the fact that one of the outstanding features of human technical practices lies in their embeddedness in the current of sociality.
>
> (Ingold 1993, 158)

Hodder (*pers. comm*., 30th November 2006, Childe Lecture, Institute of Archaeology) describes how long-termed settlement might lead to increasing investment and dependence, or 'entanglement' with things; this would have included animal herds and their areas of food resources. At the same time there might be a changing relationship between humans and their animals from the respect shown by the hunter to the hunted towards notions of acquisition or ownership by the herder for the herded (Clutton-Brock1994; Ingold 1993, 1994).

'… the initial development and later entrenchment of food production must have radically altered the nature of ownership, labor, and civic organization in Neolithic communities' (Kuijt 2000, 318). Increasing interdependence of farmers and herders might have produced a powerful coalition of interests in the social domain; but would not have developed if the two spheres operated increasingly separately. Specialisation studies might usefully be applied to these alternative models (Costin 1991), as might settlement and architectural patterning as an indicator of levels of organisation behind labour scheduling and joint ventures. Halstead's (1989) model of normal surplus as a vehicle for wealth accumulation offers insight into the

process of change from egalitarianism to social stratification.

In order to investigate the place of herding in the social and ritual life of Neolithic communities, a highly contextual, site-based approach is necessary, where datasets can provide fine spatial and chronological resolution.

1.4. Research approaches used in this thesis

The models developed in this thesis are constructed, in the first instance, through literature review, and necessarily integrate evidence from a range of archaeological and ecological disciplines and approaches.

Chronological and spatial trajectories of herding practices in southwest Asia, which might have contributed to the knowledge base of Çatalhöyük herders, may be provided by overarching regional models, whilst closer interpretation of sheep herding in settlements antecedent and coeval to Çatalhöyük draws on the environmental and historical contextualisation of site-based evidence. The Çatalhöyük palaeoenvironment is modelled using multi-scalar temporal and spatial resolution, and the ways in which herders managed their herds and their food resources in that palaeoenvironment, as well as how they might have scheduled their work in articulation with crop cultivation and other spheres of organisation in the community, may be modelled through a combination of ethological and ethnographic information.

1.5. Research methods

In order to expand knowledge of the seasonal management of domestic sheep herds and their food resources, the choice of methods used in this thesis is aimed towards providing highly contextual detail for individual sheep, and tailored to provide data relevant to the seasonality of breeding and movement to targeted resources throughout life and before slaughter.

1.5.1. Analysis of on-site zooarchaeological assemblages

Basic methods used to record and analyse zoological assemblages have been well rehearsed (e.g. Klein & Cruz-Uribe 1984; Lyman 1994) and will not be reviewed here. As in the previous section, a series of topics relevant to this thesis are posed.

1.5.1.1. Identification of domestication

Biologically domestic herd animals may be distinguished from wild progenitors using a number of criteria, however many of these are now under scrutiny. Firstly, pathologies can be associated with impoverished diets and captivity (Baker & Brothwell 1980), although these can equally be associated with earlier periods where animals were controlled – cultural control – before biological indicators of domestication emerged. Secondly, there are morphological differences in certain elements, although plasticity of horn presence undermines discrimination between wild and domestic sheep (Zeder 2006). Thirdly, zoogeographical modelling of wild sheep habitats identifies likely regions of domestication (Uerpmann 1987); although ethnographic information suggests that the habitats might have been considerably more extensive than they are today (Peters *et al.* 1999).

Fourthly, reduction in body size is widely used to identify biologically domesticated herd animals (e.g. Helmer 1992; Hongo & Meadow 1998; Legge 1996; Peters *et al.* 1999, 2005; Russell & Martin 2005). Legge (1996) voices a strong critique of the use of body size alone, arguing that the methods of size comparison are weak; wild sheep vary considerably in size in different regions as a function of climate and resource availability; and the log-size indices (LSI) method of amalgamating body-size data and comparing it to a standard animal overlooks non-allometric size change. Displaying individual element size information alongside the LSI goes some way to addressing this problem (Legge 1996; Meadow 1989; Russell & Martin 2005).

As a final caution against overreliance on morphometric criteria, Legge (1996) warns that in sexually dimorphic herd species very large assemblages are needed to morphometrically separate male and female clusters from wild and domestic ones. Zeder (2006), however, uses sexual dimorphism to separate the morphometric evidence in males and female goats. She builds on Hesse's (1978) methods (discussed further below) to show that interpreted body size reduction, associated with domestication, might, in fact, be due to a shift towards culling large young males whilst keeping small females alive.

1.5.1.2. Identification of herd profiles

Redding (1981) states that in order to address directly the ways in which humans were exploiting animals, the herd cull patterns have to be examined. The most commonly used models are Payne's (1973) cull profiles for milk, meat and wool herds, constructed from ageing data in bone fusion and tooth eruption and wear. However taphonomic loss of identifiable young bone and teeth masks the true demographic of the death population (Boessneck 1969; Klein & Cruz-Uribe 1984, 43; Lyman 1994; Maltby 1985; Munson 2000; Payne 1969). Halstead (1996; 1998a) convincingly argues that, given the limitations in accuracy, cull profiles can only express the possibility of certain product goals, particularly in subsistent economies, where cull patterns might suffer from an equifinality of contributory practices.

There have been several attempts to resolve some of the equifinality problems in the construction of cull profiles. One avenue has been to attempt to separate male and female herd profiles, especially when young. Hesse (1978) and Zeder (2006) argue that it is possible to include younger material by combining age fusion data with morphometric data; they suggest that larger unfused elements are young males, and smaller fused elements are female. This analysis is largely restricted to goat herds and is less successful with sheep, which display less sexual dimorphism. As such, the method is reliant on accurate separation of sheep and goat elements. Morphological differences in sheep and goat teeth are the

subject of debate, where practices can differ between analysts (Balasse & Ambrose 2005; Halstead *et al*. 2002; Payne 1985; Zeder 2009).

A different avenue focuses on refining the information that tooth-ageing data might provide. Helmer *et al.* (2007) have adjusted the visual representation of mortality profiles to account for uneven time periods in tooth-age stages; this simple, yet effective measure allows cull patterns to be interpreted more easily. However, as each age division is now more closely scrutinised, the method relies on large sample sizes. In addition the interpretation overlooks the complexity of subsistence practices that might have pertained. Nevertheless, Vigne and Helmer (2007) argue that milk optimisation and combined milk and meat subsistence strategies can be distinguished in a number of Neolithic herd animal assemblages in southwest Asia; their analysis suggests milking was an early technology.

1.5.1.3. Interpretation of slaughter and butchery

Zooarchaeological assemblages derive from animal parts brought on site by humans, most often for their meat (Klein & Cruz-Uribe 1984) and, as such, derive overwhelmingly from animals in herd sections destined for slaughter. Animals at other stages in their lives, when, unweaned, growing to adulthood, or breeding, remain unreachable, apart from rare examples where evidence of complementary economies can be shown in linked settlements (Arnold & Greenfield 2006).

It is possible to discuss where animals were slaughtered using two zooarchaeological methods. Body-part representation, in comparison with the general utility index (Binford 1978; Brain 1981), is used to interpret how the animals were transported from the butchery site to the settlement (Perkin and Daly 1968), and butchery marks can be used to discriminate between rough preliminary butchery and more careful separation of cuts of meat for consumption.

In establishing the age of death, inherent variability and dietary-led inaccuracies in older teeth reduce tooth-ageing precision, such that O'Connor (1998) considers it impossible to predict slaughter seasons in sheep older than six months. Within-population comparisons are considered the safest way to proceed (Payne 1985).

1.5.2. Other methods

> The importance of faunal analysis for interpreting (*herd management*) in the archaeological record is apparent … The point is not to deny the utility of osteoarchaeology, but rather to argue for the necessity of archaeologists to transcend their heavy dependence upon this single data source, and to employ the fullest range of available archaeological data and methods.
>
> (Chang and Koster 1986, 111)

1.5.2.1. On-site evidence of herding practices

Architectural evidence of on-site herding may be found in penning structures; however these are often flimsy structures built on the settlement-edge (Brochier *et al.* 1992; Courty *et al.* 1991; Matthews 2005). The microstratigraphy of penning deposits can identify dung and can discriminate between trampling by sheep-sized and cattle-sized animals; where microstratigraphy can distinguish discrete caprine faecal pellets, sheep–goat separation remains challenging (Akeret *et al*. 1999, 177).

Faecal spherulites – calcareous crystalline excretions – are often found in penning deposits (Canti 1999) and have been associated with adult sheep but rarely with goats (Brochier *et al*.

1992, 55). As the time taken for spherulite formation and excretion is unknown, they provide no evidence of penning seasonality, although neonatal lamb or kid remains in penning deposits can be associated with their birth season.

In sum, it is difficult, even from microscopic analysis of archaeological deposits, to determine either the full extent of on-site penning, or seasonal versus year-round practices.

1.5.2.2. Indirect evidence of caprine dietary regimes

Many of the methodologies that might usefully investigate dietary regimes are biased towards on-site evidence of foddering, whereas herds are more commonly raised on pasture and fallow arable fields away from the settlement (Mainland 1998a, 55). In addition, these methodologies often do not discriminate between sheep and goats, despite their very different feeding behaviour.

Archaeobotanic data are primarily taken from on-site charred remains in hearths and from penning deposits; although often associated with herd animal dung, possible acting as indicators of past animal diets (Charles 1998; Miller & Smart 1984; Valamoti 2007), there are number of reservations. In order to use dung evidence to indicate herd animal diet, it is necessary to examine pellets rather than dung (stable manure) (Charles 1998; Hall & Kenwood 1998). Penning deposits might include a mix of bedding, roofing collapse (Beck 1991, 161) and old disintegrated dung; fire rake-outs include tinder, kindling, and dung that is composed of faecal pellets often mixed with other materials (Anderson & Ertuğ-Yaras 1998; Charles 1998). Fuller *et al.* (in press) show that wild seeds assemblages from Late Neolithic contexts in southwest Asia where herding was central to the economy are not markedly different from those that could only have derived from crop-processing waste (in northern Europe where dung was probably not used as fuel, in the New World where there were no herd animals; and in the earliest pre-pottery Neolithic of southwest Asia before domestic herding); the authors suggest that plant seeds arriving on-site in dung only contribute background noise, and that most can be associated with crop processing.

In addition, passage through the sheep digestive track can take up to eight days (Akeret *et al*. 1999, 178; Simao Neto *et al.* 1987), and digestive processes heavily bias in favour of small,

hard, weed-seeds excretion, with significant loss of cereal grains and chaff to digestion (Anderson & Ertuğ-Yaras 1998; Wallace 2007). Phytolith evidence in faecal pellets reveals more detail of grass and cereal consumption, but cannot distinguish between dicotyledonous materials, such as legume by-products or leafy browse (Ryan 2010). Archaeobotanical material in faecal pellets might represent grazed food, growing within the last two weeks and selected by the herd animal, or it might be fodder, collected at some point in the past and stored, possibly for many years. Charles (1998) suggests that, in pellets, weed seeds that are not associated with cropping plants suitable for human consumption, are more likely to have been eaten by herd animals as graze or fodder.

1.5.2.3. Direct evidence of caprine dietary regimes

Other methods used to elucidate herd animal dietary regimes are directly related to individual animals, and can therefore investigate variety in more detail. One method is the examination of linear enamel hypoplasia, as an indicator of periods of stress that might arise from poor feeding (Peters *et al.* 2005). As yet, the application of this method to caprine teeth lacks the precision necessary for identifying seasonal or age-related causes.

Another method is dental microwear analysis. Dental microwear are the ephemeral marks on the enamel surface; the shape and quantity of these marks can indicate dietary regimes in the weeks before death; and in some can distinguish between fodder and graze (Mainland 1998a). The precision of dental microwear analysis is a valuable interpretative tool in investigating herding practices associated with pre-slaughter animals, and is a non-destructive technique.

Isotopic signatures in animal tissue provide signatures of grazing and foddering. Carbon assimilation varies in plants with different photosynthetic pathways (C4, C3, CAM), giving distinct $\delta^{13}C$ values (Hongo *et al.* 2009; Pearson *et al.* 2007; Richards *et al.* 2003). Nitrogen stable isotope values are more enriched in individuals higher up the food chain (Lösch *et al.*

2005), and can indicate diets rich in legumes or manured crop plants (Bogaard 2005; Hongo *et al.* 2009).

Carbon is incorporated into organic and inorganic material and is therefore found in bone and enamel, whereas nitrogen is incorporated into the organic components, and is effectively absent in enamel. As bone undergoes continual, but slow, remodelling, its isotope levels reflect an average of diets in an animal's life; however bone components are susceptible to diagenisis. Tooth enamel forms early without remodelling and provides a more precise time capsule of dietary regime, it is also less susceptible to diagenesis (Hillson 2005). Isotope analysis of bone and teeth is destructive.

1.5.2.4. Direct evidence of herding movement

Strontium stable isotope ratios (^{86}Sr: ^{88}Sr) vary in rock types, and move into the soil and groundwater, and then into the food-chain, substituting for calcium in bone and enamel (Bentley *et al.* 2003, 2004, Price *et al.* 2002). Where palaeosoils are identifiable and where the geology has marked differences in ^{86}Sr: ^{88}Sr ratios, sampling from different skeletal elements in humans can trace movement during the lifetime, as the elements remodel at different ages (Bentley *et al.* 2003, 2004, Price *et al.* 2002). However, this is less successfully applied to caprines as their lifespan is much shorter than humans.

Another method that identifies the extent of herd movement studies the robustness of limb bones. Measures of cortical thickness ratios in sheep distal humeri are greater in sheep that have undergone long, transhumant journeys than in those that remain near the village (Zeder 1978).

1.5.2.5. Direct evidence of herd management seasonality

There are several methods that might identify the season of death in animal remains from archaeological sites. Some claim that tooth cementum density is associated with annual

cycles of food availability (Klein & Cruz-Uribe 1984, 44), and that a count can give the age at death, and the density of the last band can indicate the season of death (Beuls 2004; Liebermann 1993). However, this is a poorly understood, destructive technique with numerous problems; for example, the bands might relate to hormonal levels rather than diet (Klein & Cruz-Uribe 1984, 44).

In high-crowned ungulates, such as herd animals, enamel formation proceeds from crown to cervix over a fixed period and so sequential sampling for stable isotope analysis can improve resolution and capture a record of seasonality. Strontium and carbon stable isotope analysis, respectively, can reveal annual changes in the herd animal's location and diet (Balasse *et al.* 2002; Meiggs 2007).

Oxygen is incorporated into mammalian body tissues from ingested water (Kohn *et al.* 1998), where the isotopic composition (^{16}O: ^{18}O) of the water is ultimately determined by temperature, latitude, altitude, relative humidity and distance from oceanic sources (Dansgaard 1964). Oxygen isotope analysis of sequential enamel samples has been used to pinpoint the seasonality of annual patterns in dietary regimes and herd movement seen by analysis of other stable isotopes (e.g. Balasse *et al.* 2002; Bocherens *et al.* 2001; Makarewicz & Tuross 2006; Mashkour *et al.* 2002). In addition, the known resolution of enamel formation allows its oxygen isotope values to be used to establish birth seasonality (Balasse *et al.* 2003).

1.5.2.6. Evidence of product goals

Increasing dependence on secondary wool or milk products might be signalled in the material culture by spindle whorls and by pottery residues with chemical signatures of milk lipids (e.g. Evershed *et al.* 2008). Calcium stress in cortical bone can be associated with intensive milk outtake (Horwitz & Smith 1990).

1.5.2.7. Evidence of the place of herding in the society

Contextual studies search for evidence of herd animals or herding practices in imagery and installations, or for herd animal remains as grave goods, in order to test their importance to the social and ritual life of a settlement.

Social organisation, for example the degree and nature of any herding specialisation, might be revealed in toolkits. Outside the settlement, architectural evidence of satellite camps near water sources and good grazing land, with associated storage, penning, toolkits and burials might indicate more distant herding practices (Chang & Koster 1984, 112).

1.6. Research methods used in this thesis

Published analyses of zooarchaeological assemblages can provide an underlying interpretation of the management of herd animals, but are restricted to on-site evidence which cannot approach how herding arrangements might have varied at different points in the lives of the animals. Published archaeobotanical evidence has provided the most evidence of off-site herding through analysis of dung remains but cannot distinguish grazing from foddering, nor sheep from goats.

Dental microwear and carbon stable isotope evidence provide the most direct evidence of dietary regimes. Carbon stable isotope analysis discriminates between C4- and C3-rich diets, but are difficult to interpret in Mediterranean vegetation zones (van Dam & Reichart 2009) and, in any case, are already studied in depth at the case site, Çatalhöyük. Dental microwear analysis can discriminate between fodder and graze diets in different environmental conditions. It gives high-resolution evidence of pre-slaughter feeding regimes, useful to this thesis.

Strontium stable isotopes provide evidence of movement seasonality, but cannot define the precise season. Oxygen isotope analysis of sequential tooth enamel samples provides direct seasonal evidence during the period of enamel formation. In certain sheep teeth it is possible to investigate both the birth season and the first year of its life. Ethnography shows (*Chapter 6*) that young lambs, with their mothers, are commonly herded together in breeding herds separately from older animals, but that after a few months they join the older animals in larger herds – fallow herds – whilst they grow to maturity. Thus, oxygen isotope analysis of targeted teeth might give insights into the management of both breeding and fallow herds.

Both oxygen stable isotope and dental microwear analyses, when applied to sheep tooth enamel, give direct evidence at the resolution of a few weeks in individual animals. The power of the combination of these analyses is three-fold. Firstly, both take their data from the same source, taphonomically robust sheep teeth, ensuring that interpretation is specific to an individual. Secondly, they provide information of birth, of early life and of the last weeks of life, providing a skeleton biography for individual animals, and partial information on the management of herd parts designated for breeding, fallowing and slaughter. Thirdly, both analyses inform and constrain each other when interpreted within palaeoenvironmental reconstruction and ethological and ethnographic evidence.

1.7. Theoretical framework

The study of the past, in any field, is inevitably dependent on analogy to the present, unless historic continuity can be established. Analogy is dependent on uniformitarian assumptions which can be more closely controlled where there is an accumulation of common features; the palaeosciences are able to use analogy with the greatest confidence (Gifford-Gonzales 1991, 220). Understood within the constraints of their own datasets, it is possible to address

comparable questions in a range of palaeoscientific data, and to establish broad ecological models (Chang & Koster 1984, 131).

Analogy can also be used to address human behaviour. The observable association of material evidence to socio-cultural behaviour in the present can be linked to the material evidence from the past, and then, by inference, to past socio-cultural behaviour (Gifford-Gonzales 1991, 220). Archaeologists attempt to control uniformitarian assumptions by establishing rigorous, testable models, or by close contextual analysis of the evidence. However, other archaeologists argue that uniformitarian-led biases cannot be excluded, especially as data is inevitably selected and prioritised according to the researcher's underlying assumptions and beliefs (Tringham 1991, 112); consequently they offer their interpretations as one voice amongst many.

Analogies drawn from ethnographic information are widely used in archaeology. Formal analogy takes information that is consistent across a number of societies to establish uniformitarian principles, and relational analogies include the contexts of artifactual information (Verhoeven 2005). Central to the use of ethnographic analogy in interpretation is an understanding of the bias to assemblages introduced by site-formation processes, and of possible uniformitarian assumptions about form, function and meaning (Verhoeven 2005).

Where ethnographic analogy is used, there are dangers in using deductive reasoning to set up hypotheses, as this creates fixed categories of data limited by modern understanding (Meadow 1992, 262). Scientific validity is, in any case, questionable, as it is effectively impossible to prove or refute the archaeological past (Verhoeven 2005). The ethnology of relevant traditional cultures might most safely be viewed as indigenous knowledge, adding useful information to modern knowledge.

Processual archaeology asks why societies change, modelling societies as systems, where the inputs are the pressures that cause those systems to adapt. If successful, the newly adapted society is selected for, and takes its place in the path of progress. Processual archaeology bases itself in evolutionary theory and in Marxist economic theory. Processualism is a deterministic model, where humans passively respond to pressures such as the climate, land resources or demographic pressures. Systems analysis is limited to measurable inputs, where empirical data can be interrogated with scientific logical positivism.

Evolutionary theory underpins much processual archaeology, and has been used to model economic and socio-cultural spheres. Human behavioural ecology draws out determinants of behaviour to understand which ecological variables are influencing human activities. For example, optimal foraging strategy weighs the energy returns from different food sources against the energy outlay required to retrieve that food. It argues, on evolutionary principles, that the optimal resource will always be selected (Russell 1988). However, the principles are violated in the Neolithic by ritual use of animals (Keswani 1994), by the uptake of low-ranking cultivated plants and by deferring high-ranking meat rewards through practicing animal herding in a period of ample resources (Zeder 2006, 111).

Niche construction theory is within the neo-evolutionary paradigm and provides an interesting model of human–animal relationships. Niche construction refers to the capacity of organisms to construct, modify and select components of their local environments. Through niche construction, organisms not only influence the nature of their world in a non-random manner, but also, in part, determine the selection pressures to which they and their descendants are exposed (Day *et al.* 2003). Niche construction extends the phenotype to include ecological inheritance, where niches are constructed out of the bits and pieces of the

world, allowing the organism to persist in an inhospitable environment; in humans, this ecological inheritance is cultural transmission (Smith 2007). Niche construction provides an overarching explanation of domestication, and also encompasses the small refinements and mistakes taken by animals and humans as they increasingly invest in the construction of their niche.

Niche construction is not just adaptation by another name. Firstly, it does not assume a steady and predictable decline from optimal to marginal habitats, but allows new niches to be constructed in unexpected anthropogenic settings, where circumstances have created overlapping niches (Uerpmann 1996, 228). Secondly, niche construction provides a theoretical framework that links human action to changing plant and animal niches. Addressing the earliest management of animals and plants, Terrel *et al.* (2003, 332) suggest no new facts are needed in finding the best fit for animals and plants in more marginal anthropogenic environments, and Ingold (1996, 21) argues that, with domestication, all that was changing was 'the relative scope of human involvement in establishing the conditions for growth'.

Post-processual archaeology is interested in the agency humans have in decision making, in terms of social processes rather than human behaviour. It examines the impact of small-scale events, associated with human action and choice, on changing societal structure (Marciniak 2005, 5). Drawing on structuation theory, Bourdieu (1977) argues that structuring principles, or rules, inform practices and social action. He uses the term *habitus* to describe how actions are a product of history, learnt unconsciously from rules embodied in everyday actions and objects around them, such that the actions are sensible and reasonable, and serve to reinforce the rules.

The datasets used by post-processual archaeologists are commonly taken from the material culture. Rigorous contextual spatial analysis is compared to ethnographic examples in order to infer, by analogy, the rules, or *habitus,* relating to the sphere of social activity.

Zooarchaeological remains are highly suitable for contextual analysis as 'human actions appropriate to one member of such a category are very likely appropriate to any member of that category' (Hunn 1982, 833). Everyday practical activities, such as herding, can be studied validly within this paradigm as they cannot be separated from the mutual involvement, or social relations, of people (Ingold 1993, 160) and as dwelling in the landscape may be seen as an active process of being with, and attending to, other living things and objects in the world (Ingold 1996).

By adding a temporal dimension to contextual analysis, it is possible to infer social memories, constructed by the reiterative practices of tradition and ancestry (Hodder & Cessford 2004). Social memory can be explored through the routines of herding in the landscape; this 'taskscape' is the seasonal rhythms of the landscape, humans and animals (Ingold 1993, 163). Social memory contributes to social identity and group cohesion (Ingold 1994, 7; Nandris 1990). Hodder's theoretical approach of increasing involvement, or 'entanglement', resonates with the increasing investment of humans and animals in the construction of their niche (Smith 2007).

Giving visibility to groups allows interactions and hierarchy to be explored (Tringham 1991, 117). Specialisation by different individuals or groups can be inferred most directly by the spatial distribution of toolkits in the archaeological record, but also by evidence of a greater reliance on certain products, increased labour scheduling efficiency, greater time allocation, and more standardisation of practice (Costin 1991, 16–17, 42). Interdependence between different activities, where the product of one activity becomes the raw material for another,

can be explored (Clarke 2007, 5, *citing* B. Sillar, n.d.). Skill and knowledge of special materials can enhance the power of an individual or a group (Wright *et al.* 2008).

Culture history aims to define cultural groups by their material culture, and explains cultural change as the result of diffusion, either of people (demic), ideas (acculturation) or both. Expansionist theories establish a unilinear spatial and chronological trajectory from a single core out to its periphery (e.g. Ammerman & Cavalli-Sforza 1973), whilst polycentric models argue for regional diversity, but with similar diffusionist models (e.g. Gebel 2004). Areas of common practice might be considered as interaction zones, where trade networks increased the scope for acculturation and integration (e.g. Bar Yosef & Belfer-Cohen 1989).

As knowledge accumulates, more complex explanations for change are demanded in order to encompass the different trajectories taken by different settlements. Many of these explanations are highly contingent on the environment and history of each settlement, re-framing the culture-history paradigm within small scale, site-based models (e.g. Rowley-Conwy 2000).

However, settlements did not exist in isolation; the exchange of ideas and things was socially situated, and the negotiation and reproduction of group identity would have been integral to exchange (Asouti 2006, 4; Kuijt 2000). Furthermore, where settlements resulted from migrations, a historic dimension of the ancestral groups is likely to have been maintained, perhaps apparent in the material culture of the settlement. The study of one settlement '… is useful not only with regard to specific local events and processes but, furthermore, as a compass for gaining meaningful insights into the structure and trajectories of Neolithic societies across the region (Asouti 2006, 13).

1.8. Theoretical framework to this thesis

This thesis uses two scientific datasets (dental microwear and oxygen isotopes in enamel) which have been fully tested and understood within bio-ecological and bio-chemical sciences. The same datasets in archaeological material are strongly analogous to modern ones, through biological science theory. In order to model the environment in which the archaeological datasets were formed, a broad ecological approach integrates archaeobotanical, zooarchaeological and geoarchaeological evidence, all understood within similar analogous relationships to theories of natural sciences.

In order to interpret the behaviour of Çatalhöyük sheep, two theoretical frameworks are used. The first assumes an underlying uniformitarian relationship between early domestic sheep and wild sheep from the same landscape. The case for this is strengthened by comparing wild sheep ethology to behaviour in modern domesticates, using evidence from zooarchaeological, agricultural and veterinary sciences, and from indigenous knowledge (Chapter 6).In particular, analogy will be drawn between the behaviour of wild herds where they split into breeding and non-breeding sections for much of the year in order to manage aggression and target resources, and the herd splitting practices of domestic herders in order to control breeding ,maintain herd security and conserve resources. In addition, their breeding herds, consisting of ewes and lambs in their first few months, and fallow herds, made up of non-breeding animals growing to maturity, herders commonly fatten up a targeted selection of mature animals just before slaughter. Breeding, fallow and slaughter herds are conceptual distinctions that are well grounded in ethnographic and ethological reality, and so it is argued in this thesis that similar herding arrangements would have, of necessity, pertained in the Neolithic.

The second theoretical approach describes as niche construction any small changes in sheep behaviour which might have facilitated their survival in new anthropogenic environments. Niche construction theory has the advantage of bridging sheep behaviour and herding practice, where small adjustments in herding practice can also be understood in terms of niche construction. Interpretation in this thesis draws on palaeoenvironmental reconstruction (Chapter 5) to model how herd parts might have been spatially dispersed in order to target and conserve resources whilst optimising herd security. The model incorporates constructed niches arising from the constraints or opportunities that might have arisen from arable farming.

This ecological heritage (in sheep), or cultural transmission (in humans) is part of the dwelling in, or attending to, the landscape; a part of depending on, entailing and entangling with objects. Herding is a social activity, contributing to social memory and tradition within and outside the settlement. By making herding more visible, as a group of people or as a specialist activity, group cohesion and power relationships can be discussed. Structuation theory, such as *habitus*, is the theoretical basis best suited to describe how herder action is circumscribed by social rules. To understand how those rules came into being this thesis draws on Asouti's (2006) dialectical model of migratory traditions versus group identity.

1.9. Summary

In summary, the challenge is to understand herding practices within highly contextual decision making, where environmental limitations and socio-cultural factors interact. Çatalhöyük, a mixed agricultural, later Neolithic settlement in central Anatolia, is chosen for a site specific approach. Two scientific datasets, oxygen isotopes and dental microwear in tooth enamel, are selected to provide highly contextual evidence of birth season, movement during the first year, and diet before death at a resolution of individual sheep. The results are

compared, by analogy based in natural sciences and the ethnology of herding, to the modelled seasonal protection and feeding needs of animals at three stages in their life histories; when they are members of breeding, fallow and slaughter herds. It is now possible to propose the niches constructed for domestic sheep at different points in their life history. Interpretation first draws on the published research on Çatalhöyük's economic sphere and its palaeoenvironment, and introduces human agency into the construction of the sheep herding niche through discussion of the social and ritual spheres within the settlement and within the wider temporal and spatial context.

Having established the approaches, methods and theoretical parameters of this thesis, the first chapters undertake a literature review that will be used to contextualise the interpretation of the evidence central to the original research presented in the thesis.

CHAPTER 2. THE REGIONAL CONTEXT

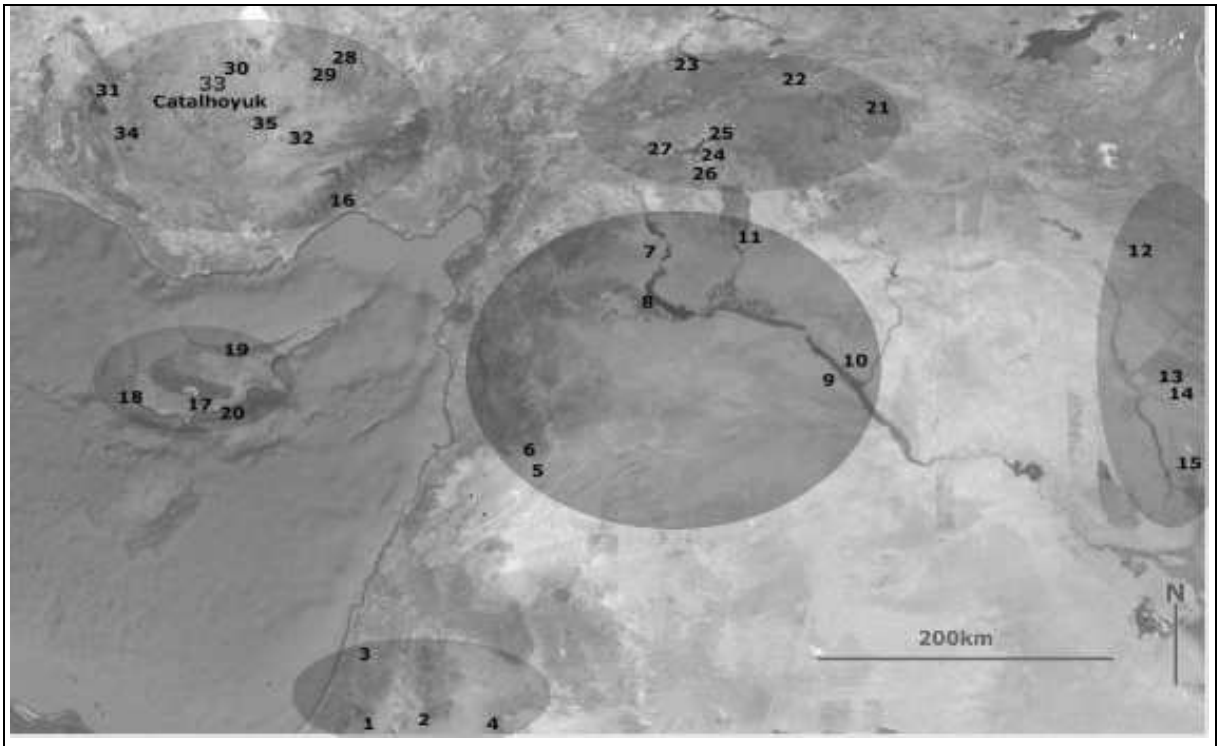
2.1. Introduction

Caprine herding in early settlements can be approached through comparing the potential knowledge base of herders to what they actually practiced in one settlement, highlighting matches and mismatches for further interpretation. This chapter establishes the first part of such a comparison – the repertoire of practices available to Çatalhöyük herders – through literature review of the evidence for herding in southwest Asia.

The review divides southwest Asia into six geographical areas (*Figure 2.1*), and covers the mid 9th to early 7th millennia cal. BC Neolithic, focusing most closely on central Anatolia. The areas are not intended to define cultural entities; the north Levant area is an arbitrary division where it would have been equally possible to subsume the Euphrates sites into the southeast Anatolia area, and the Damascus Basin sites into the south Levant area. The southern, arid region of the south Levant has not been included.

2.2. Dating the Neolithic of southwest Asia

A relative chronology was established in the south Levant, based primarily on lithic and pottery typologies from the long sequence at Jericho (Kenyon 1957). The first sub-division separates the Aceramic and Ceramic Neolithic; each has been further divided. Inter-area typological differences have necessitated Levantine labels to be qualified or have provoked complete re-classification (e.g. Early Ceramic Anatolia system; Özbaşaren & Buitenhuis 2002). Furthermore, there are intra-area differences between neighbouring settlements arising from historically contingent cultural, environmental or site function differences (Betts 1993).



southeast Anatolia	*Zagros*	*north Levant*	*Cyprus*	*south Levant*	*central Anatolia*
21. Hallan Çemi 22. Çayönü 23. Cafer 24. Nevalı Çori 25. Gritille 26. Gürcütepe 27. Hayaz H.	12. Jarmo 13. Tepe Sarab 14. Ganj Dareh 15. Ali Kosh	5. Aswad 6. Ghoraifè 7. Halula 8. Abu Hureyra 9. Bouqras 10. T. es Sinn 11. T.Sabi Abyad II	16. Yumuktepe (mainland coast) 17. Shillourokambos 18. Mylouthkia 19. Akanthou 20. Khirokitia	1.Jericho 2. Yiftah'el 3. 'Ain Ghazal 4. Azraq 31	28. Aşıklı H. 29. Musular 30. Boncuklu H. 31. Süberde 32. Canhasan III 33 Çatalhöyük 34. Erbaba 35. Pınarbaşı

Figure 2.1.
Map of southwest Asia showing the sites referred to in the text

With the advent of radiocarbon dating, Neolithic cultural periods were given absolute dates which confirmed inter- and intra-regional differences in the timing and duration of cultural phases. Absolute dating has been further refined, using calibration curves constructed from dendrochronological sequences, ice-cores, lake varves and speleothems (Stuiver & Reimer 1993), and now encompasses the whole Neolithic. The most recent dating methods apply statistical packages (e.g. Aurenche *et al.* 2001) to establish the best fit of dates and periods. Unfortunately too late for this thesis, Bayesian statistics are being applied to a tranche of new secure dates from Çatalhöyük (Bayliss & Farid 2008).

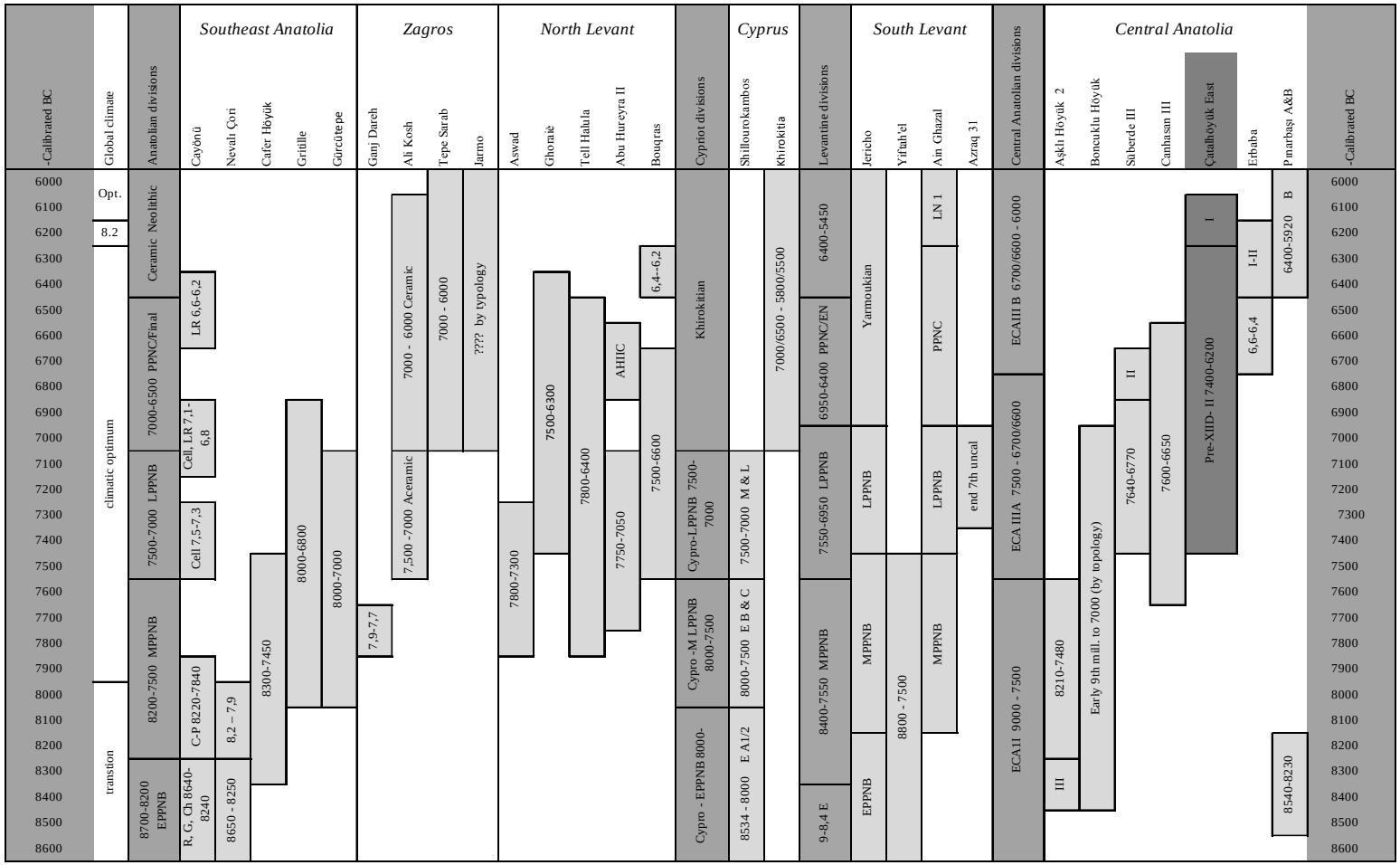


Table 2.1.
Chart summarising the chronology (cal. BC) of cultural periods and settlements in southwest Asia.
After Thissen 2001, 2007; Thissen & Bischoff 2006

Cultural labels have been avoided in this thesis, and dates expressed in calibrated radiocarbon years (cal. BC) have been used in preference; where sites have uncalibrated dates, Aurenche *et al.*'s (2001, 1200) conversion chart is used. Rollefson (1989) warns that any attempt at a temporal and spatial synthesis of sites in southwest Asia has to be arbitrary given the size and variety of the area, the significance of new information from unstudied areas, and the improved dating, excavation and interpretative techniques. The synthesis attempted in this chapter (*Table 2.1*) is solely a framework for discussion.

2.2. Overview of the Neolithic of southwest Asia

Within the confines of this thesis, an overview of the Neolithic of southwest Asia is necessarily brief, however more detail is summarised for each site discussed, by reviewed area, in *Appendices 1–6.*

The Neolithic of southwest Asia emerged during the Holocene after the Younger Dryas (11000–9500 cal. BC) – a brief reversal in post-glacial climatic amelioration. The first evidence of cereal cultivation coincided with increased temperature and precipitation (Hillman *et al.* 2001). Climate amelioration advanced, with a short-lived reversal (6500–6000 cal. BC), until reaching its optimum in the mid-6th millennium cal. BC (Weninger *et al.* 2006). During this time the domestication of herd animals and mixed agricultural economies were established.

Preceding the Neolithic, there is multiple evidence of year-round sedentism in the early 13th millennium cal. BC (Bar-Yosef & Belfer-Cohen 1991, 188). Settlements congregated in ecotonal settings, where the habitat of each area determined which large herbivores were hunted alongside a broad spectrum of smaller animals (Bar-Yosef & Belfer-Cohen 1991).

Coinciding with the start of the Holocene, *c.* 9500 cal. BC, sedentary villages of semi-subterranean round houses grew in size and number (Bar-Yosef & Belfer-Cohen 1991, 191). In southeast Anatolia there is evidence of expanding elaborate public ritual in dedicated centres (A. Belfer-Cohen & N. Goring-Morris, *pers. comm.,* March 2009, Wenner-Gren International Symposium). Single unadorned burials were the norm, and some skulls were removed, plastered, and buried inside houses (Bar-Yosef & Belfer-Cohen 1991, 192). Exchange networks included contact with obsidian sources as well as colonisation of Cyprus (Peltenberg 2003). A broad-spectrum hunting economy continued, but evidence indicates that domesticated cereals and pulses were supplementing gathered plant foods (Bar-Yosef & Belfer-Cohen 1991, 191), and there were various attempts to control or manage a range of herd animals (Hongo & Meadow 1998), including live animal transportation to Cyprus (Vigne *et al.* 2000).

In the south Levant, settlements were short-lived, but to the north many settlements were long-lived and new ones were established (A. Belfer-Cohen & N. Goring-Morris, *pers. comm.,* March 2009, Wenner-Gren International Symposium). Evidence suggests the north Levant and southeast Anatolia were now at the forefront of technological and economic innovation (Bar-Yosef & Belfer-Cohen 1989, 1991; Peters *et al.* 2005), raising interest in mechanisms of spread to other areas (Cauvin 2000; Clarke 2007; Ducos 1993; Peters *et al.* 2005). At this time, before 8500 cal. BC, Aşıklı Höyük, in Central Anatolia, was settled (Esin & Harmankaya 1999).

By 8700 cal. BC, villages in more temperate zones were built of undifferentiated rectangular mud-brick houses, often plastered, painted or decorated (Bar-Yosef & Belfer-Cohen 1991, 193); in more arid margins, villages were small and buildings retained sub-rectangular forms. Earlier ritual sites in southeast Anatolia were re-located in public areas or buildings within many villages (A. Belfer-Cohen & N.Goring-Morris, *pers. comm.,* March 2009, Wenner-Gren International Symposium) and ,n central Anatolia in the following

millennium, ritual became less public and was commonly situated in dedicated rooms within houses (Hodder & Cessford 2004, 18). The chipped-stone assemblage, heavily reliant on obsidian, was dominated by large blades and flakes (Bar Yosef & Belfer-Cohen 1991).

The hallmark of the late 9th millennium cal. BC, and on into the the first half of the 8th millennium, was an increasingly complex and established communication network throughout and beyond southwest Asia, allowing earlier diversity of food production systems to integrate, resulting in reduced variety (Wasse 2007). It was now, during the climatic optimum, that a greater reliance on domestic crops and unequivocal evidence of successful animal control saw the widespread establishment of mixed agricultural economies (A. Belfer-Cohen & N. Goring-Morris, *pers. comm.,* March 2009, Wenner-Gren International Symposium).The first domestically herded sheep and goats appeared in areas of their natural habitat, and rapidly spread elsewhere (Bar-Yosef & Belfer-Cohen 1991, 193; Martin 1999). Çatalhöyük was settled *c.* 7400 cal. BC as a mixed agricultural settlement.

The period *c.* 7000 cal. BC is marked by the rapid addition of pottery to the material culture (Last 2005a). Early plant-tempered forms gave way, in a clear horizon seen across southwest Asia 6600–6400 cal. BC, to a greater variety of mineral-tempered, highly fired forms (Last 2005a). In the south Levant there was wide-scale abandonment of 'mega-sites' and the establishment of more dispersed settlements, some in coastal locations (Galili *et al.* 1993*;* Kuijt 2000). Elsewhere, a few settlements, such as Çatalhöyük, continued to flourish, maintaining conservative large village traditions but rapidly incorporating new technologies.

The new dispersed villages had open settlement plans of larger lime-plastered houses, some with two storeys (Kuijt 2000). Sickle blades continued to dominate the lithic assemblage, whilst tanged arrowheads became smaller and less common (Bar Yosef & Belfer-Cohen 1991). Burials were more often outside buildings and skull removal was no longer practiced (A. Belfer-Cohen &N. Goring-Morris, *pers. comm.,* March 2009, Wenner-Gren International

Symposium). Mixed agriculture now dominated and hunting was largely replaced by domestic sheep but with increasing domestic cattle herding (A. Belfer-Cohen &N. Goring-Morris, *pers. comm.,* March 2009, Wenner-Gren International Symposium). In central Anatolia these changes appeared later. The Neolithic Çatalhöyük settlement was abandoned c. 6200 cal. BC and relocated on the opposite bank of the Çarşamba River.

2.3. Review of herding evidence

The purpose of this section is to contextualise herding practices at Çatalhöyük through a review of the evidence and interpretation of the food economy in key sites in southwest Asia. The review restricts itself to village sites and does not explore zooarchaeological evidence from ritual centres. Sites with large zooarchaeological assemblages and a corpus of published analyses that have contributed to key research questions are reviewed in most detail, but it should be emphasised that they are not chosen as being representative of their region or period.

2.3.1. Southeast Anatolia

Of the six areas under review, the first is southeast Anatolia, south of the Taurus Mountain watershed. The evidence of early monumentality contributes to discussion on the maintenance of social cohesion in the early Neolithic (Schmidt 1996). Challenges to earlier models of linear progression towards mixed agriculture emerge, and the first herd animal domesticates are debated (Hongo & Meadow 1998; Peters *et al*. 2005). It is here that the earliest evidence for sheep management and full biological domestication is found (Hauptmann 1999).

2.3.1.1. Çayönü Tepesi

Çayönü Tepesi B (Çambel & Braidwood 1980; Özdoğan 1977) was occupied throughout the Neolithic. Of its five building phases, the Cell (7510–7350 cal. BC), Cell–Large Room

transition (7140–6820 cal. BC) and Large Room (6640–6270 cal. BC) phases are contemporaneous with Çatalhöyük.

	NISP	Sheep & goat	Pig	Cattle	Red deer: cattle ratio
Cell	34	18	32	29	
Cobble- paved	200	21	26	23	1:1.3
Channelled	144	24	60	6	1:0.7
Grill	284	16	43	21	1:3
Round	287	12	45	24	1:4

Table 2.2
Çayönü NISP percentages of large meat bearing animals.
After Hongo & Meadow 1998; Hongo et al. *2009; Ilgezdi 2000;Öksüz 2000*

The first zooarchaeological analyses discuss the assemblage as a whole, and do not describe retrieval methods (Lawrence 1980; 1982). Small sample sizes and re-assigned levels make interpretation insecure for earlier levels in particular (Legge 1996, 245), but Hongo *et al.* (2009) argue for a suite of approaches that makes the use of LSI (log size indices) in small assemblages more secure.

Pigs, sheep and goats dominated (*Table 2.2*), followed by cattle and red deer (Lawrence 1980, 285). In earlier phases pigs were extensively exploited; morphometric and ageing data from a larger, stratified assemblage indicate their management (Hongo & Meadow 1998, 83). By the Channelled phase, hunted red deer had become more important than wild cattle (Ilgezdi 2000; Öksüz 2000), and morphometric, sex and age data, and isotope indicators of foddering show temporal changes in cattle interpreted as evidence of early management during the mid-9th millennium (Hongo *et al.* 2009).

Analysis of a larger, stratified assemblage suggests that caprines increased in importance during the Cell phase (10%–26%), rising to 80% in the Large Room phase (Lawrence 1982; Özdoğan 1999, 52). Goats dominated the earlier assemblages and sheep the latter, in a sheep to goat ratio that changed from 3:10 to 2:5 (Lawrence 1980, 300). The small goat assemblage (NISP = 74) makes interpretation of their domestic status insecure, although there were more large individuals in earlier phases (Legge 1996, 245). Using sheep (NISP = 135) morphometrics and horn morphology, Lawrence (1980, 287) proposes there were wild and domestic sheep throughout; this view is supported by Legge (1996, 245). In addition, caprine dung increased on site (Brochier 1993). In summary, there appears to be synchronous early management of the four main domesticates between 8800–8300 cal. BC, followed by rapid intensification in caprine exploitation (Hongo *et al.* 2009, 72).

2.3.1.2. Other southeast Anatolia sites (*Figure 2.3*)

Nevalı Çori (Hauptmann 1999) was settled on an upper Euphrates tributary at approximately the same time (8650–7950 cal. BC) as the Grill, Channelled and Cobble-Paved phases of Çayönü. There was an increasing reliance on caprines, cattle and pigs, rising to 15% (Peters *et al.* 2005). Morphometric, age and sex data suggest sheep, pigs, and possibly goats, were fully domesticated by 8240 cal. BC (Helmer *et al.* 2005; Peters *et al.* 2005). Stable isotope values in human and animal bone point to foddering practices (Lösch *et al.* 2006).

Cafer (Çambel & Braidwood 1980; Özdoğan 1977) was occupied a little later from 8300–7450 cal. BC at the time of the Cobble-Paved and early Cell phases of Çayönü. Caprines (53–63%) dominate the zooarchaeological assemblage (Helmer 1991, 133). In contrast to Nevalı Çori, the LSI, individual element measurements, and cull patterns suggest caprines were wild, although early cattle and pig management was possibly in place (Helmer 1988, 45–48). Helmer (2008) re-analysed the small assemblage using Kernel analysis and succeeded in demonstrating pig domestication although sheep, goat and cattle status remains uncertain (Helmer 2008, 177–189).

Gritille (Ellis & Voigt 1981) was occupied 8000–6800 cal. BC, and coincided with Çayönü late Cobble-Paved and Cell phases. Caprine exploitation rose from 64% to 74% (Stein 1989), with a sheep to goat ratio of 3:1 (Legge 1996). From the outset many caprines were small, and tooth-age evidence points to a 65% cull before three years old, taken to be convincing evidence of domestic herds raised primarily for meat (Legge 1996; Monahan 2000; Stein 1989). The caprine cull pattern in the large Phase B assemblage fits Redding's (1981) model of risk-aversion management (Stein 1989), with flexibility provided by hunting (NISP = 3%) and small domestic pig and cattle herds. Monahan (2000, 238–240) argues that there was no intensification until the latest phase, where declining diversity became apparent in focused culling of young male domesticates and early indications of cattle management (Monahan 2000, 261).

Nearby on the Harran Plain, Gürcütepe (Hauptmann 1999) was occupied at the same time as Gritille. The evidence, summarised by Peters *et al.* (2005), also indicates that focused domestic caprine exploitation (25%) was supplemented with a few domestic cattle and pigs and also by hunting.

2.3.1.3. Summary

In southeast Anatolia there was early management of all four species 1000 years before Çatalhöyük was settled, but it was not until the time of Çatalhöyük's first occupation that people began to rely on fully domesticated sheep. If Stein and Monahan are correct, herd management did not necessitate immediate intensification, and flexible risk-management and increasing exploitation in the absence of intensification might be included in the range of strategies known to Çatalhöyük herders.

2.3.2. Zagros Area

The second area reviewed is the eastern arm of the Fertile Crescent, the Zagros Mountains, where the earliest evidence of goat management and domestication is found (Hesse 1984). Research here plays a historical role in determining questions concerning timing and centres of domestication for different herd animals (Hole *et al.* 1969).

2.3.2.1. Ganj Dareh and Ali Kosh

Ganj Dareh, in the Zagros highlands, and Ali Kosh, on the arid Deh Luran plains below, were two of a series of settlements chosen to elucidate the regional Neolithic sequence. Recent AMS dating redefines the timing of events and temporal relationships between settlements. In particular, all five levels at Ganj Dareh (Smith 1983) are now considered to have spanned only 200 years, *c.*7900 cal. BC (Zeder 1999, 15).

The Ganj Dareh assemblage has very few large sheep which were probably hunted, whereas goats, in the heart of their native habitat (Uerpmann 1987), dominated the assemblage in a sheep to goat ratio of 1:9 (Legge 1996). Hesse (1978, 304) incorporates bone-fusion and size data into his interpretation of cull patterns, and argues that hunting in the earlier level was replaced by an economy reliant on goats under early management; hoofprints in mud bricks add some support.

Interpretations based on LSI argue that goats were small and fully domesticated from the outset (Helmer 1992; Legge 1996). However, applying Hesse's (1978) methods to a larger, well-stratified assemblage, Zeder (1999, 19; 2006, 198) argues that all goats were morphologically wild but, as 80% of males were culled between one and two years old whereas 70% of females were alive at four years, were managed when Ganj Dereh was first settled.

Ali Kosh was settled 500 years later, *c.*7500 cal. BC (Zeder 2005, 130) within gazelle native habitat and on the margins of goat and sheep habitats (Hole *et al.* 1969). It was broadly contemporaneous with the Çatalhöyük occupation. The Bus Mordeh Phase was a foraging settlement coeval with the first half of the Çatalhöyük occupation, followed by the Ali Kosh Phase when cultivation was introduced, and then the ceramic Mohammad Jaffar Phase with fully established arable farming (Hole *et al.* 1969).

	NISP	Caprine	Sh: gt ratio	Cattle	Pig	Gazelle
Mohammad Jaffar	2477	28	2:3	1	0.2	17
Ali Kosh	7034	38	Rising to 1:2	3	0.3	18
Bus Mordeh	3001	44	0:1	8	0.1	15

Table 2.3
Ali Kosh NISP percentages of large meat bearing animals.
After Hole et al. *1969*

NISP percentages (*Table 2.3*) show that only goats were exploited at first, but over time the sheep to goat ratio rose to 2:3 (Hole *et al.* 1969). The sheep NISP is small, and evidence of domestication in the Bus Mordeh Phase is confined to one twisted horn core, becoming more common in the final phase (Hole *et al.* 1969). As wild sheep occasionally have twisted horns there is no clear evidence of sheep domestication when Ali Kosh was first settled (Zeder 2006, 183).

Although horn morphology suggests goats were wild in the early phase, Hole *et al.* (1969) argued that some management was in place in order for them to be introduced, and then survive outside their habitat. By the Ali Kosh Phase the amount of on-site caprine dung and culling of younger animals (Hole *et al.* 1969) suggests increased management, and Zeder's (2005, 134) closer examination of the morphometrics by sex and age shows a slight size diminution over time. Zeder (2006, 202) supports Hole *et al.*'s (1969) interpretation, adding that herd security might have demanded older cull ages at first.

2.3.2.2. Other Zagros area sites (*Figure 2.3*)

Jarmo is a highland settlement nearer southeast Anatolia, occupied for *c.* 300 years (Braidwood (1983, 537); relative dating places it contemporaneous with the early 7th-millennium Çatalhöyük occupation. The large zooarchaeological assemblage was partially retrieved from selected contexts (Stampfli 1983), providing evidence of arable farming but possibly of a slow start to herd management. Morphometrics suggest that pigs, but not sheep and goats, were domesticated in the later phase, and that hunting dominated both phases (Stampfli 1983, 437). This interpretation is challenged by Zeder (1999), who argues, on two counts, that sheep and goats were domesticated by the later phase. Firstly, there is evidence of changing horn-core morphology in both and, secondly, morphometric reassessment, incorporating sex and age criteria, identifies body-size reduction in later-phase goats.

Tepe Sarab chronologically overlaps with Jarmo and was coeval with the later part of Çatalhöyük's occupation. The NISP, horn-core morphology, reduction in body size and a young cull are consistent with reliance on domestic sheep and goat herds (Bökönyi 1977; Legge & Rowley-Conwy 2000).

2.3.2.3. Summary

The evidence from the Zagros area investigates the trajectories of another domesticate: the goat. They were first hunted, then managed and then moved outside their habitat, where closer management led to full domestication.

Çatalhöyük had fully domestic goat and sheep herds 500 years after the first goat management evidence. Surprisingly this is earlier than in other Zagros settlements, possibly as the centre of spread was elsewhere. The timing of sheep introduction at Çatalhöyük was very similar to the Zagros area settlements, again suggesting, perhaps, a shared trajectory from elsewhere.

There are two suites of practice that might have been known to Çatalhöyük herders. Firstly, the movement of goats from the highlands to the plains covered terrain and climate change similar to vertical transhumance, a possible option for herders concerned with seasonal resource conservation. Secondly, herd management was taking place before, and during, the early stages of arable farming (Hole *et al.* 1969), in an opposite sequence to south Levant settlements, and serving as an alternative economic model.

2.3.3. North Levant

The third area, the north Levant, is where the full suite of domestic crops and animals is considered to have come together in mixed agricultural settlements. The ecotonal settings were suitable for rain-fed agriculture and within, or near, the habitats of all domesticate progenitors (Hillman *et al.* 2001; Uerpmann 1987). Early innovations in many aspects of the material culture locate the north Levant as the centre of the Neolithic, raising interest in its spread to other areas (Cauvin 2000; Clarke 2007; Ducos 1993; Peters *et al.* 2005).Cattle domestication is first in evidence in the north Levant (Saña i Seguí 2000), yet its slow emergence in other areas is in contrast to the rapid spread of caprine herding and new chipped-stone and ceramic technologies (Arbuckle & Makarewicz 2009).

2.3.3.1. Abu Hureyra

The excavation of Abu Hureyra (Moore *et al.* 2000) put the development of agriculture at the centre of its research, where wet sieving did much to redress taphonomic loss of smaller bone as well as retrieving a large assemblage of charred plant remains.

Legge & Rowley-Conwy's (2000, 461) (*Table 2.4*) analysis shows that sheep increased briefly (6% to 30%) during AH1 (11,100–10,440 cal. BC) before dropping back to 12% in AH2A (mid-8th millennium), and finally rising by 7050 cal. BC (65% to 85% in AH2B and C). At the same time, the gazelle NISP% fell from 80% in AH1 to between 15% and 30% in

AH2B, and goats made their first appearance during AH2A, briefly dominating sheep by 5:1 before this ratio was reversed to 1:5 (Legge & Rowley-Conwy 2000, 463).

	NISP	Sheep	Goat	Sh: Gt ratio	Cattle	Pig	Gazelle
AH 2B	9739	65-85		5:1	2 - 7		15 - 30
AH 2A	11937	30 , then 12	++	1:5			
AH1	1471	6	0	1:0	++	+	80

Table 2.4
Abu Hureyra NISP percentages of large meat bearing animals.
After Legge & Rowley-Conwy 2000

Legge & Rowley-Conwy (2000, 465) use individual element measurements and LSI to show that sheep were slightly smaller than wild forms in AH2A, with little change into AH2B; they dismiss environment-induced size reduction (Bergmann effect) as gazelle sizes remained unaltered. Goats were slightly smaller than wild forms and, as Abu Hureyra is not in their native habitat, Legge (1996) interprets this as the introduction of early domesticates. Goat sexual dimorphism identifies young male and older female culls in AH2B and, by extrapolation, in AH2A (Legge & Rowley-Conwy 2000, 469); sheep, however, could not be tested.

Legge & Rowley-Conwy (2000, 468) interpret the ageing evidence as pointing to sheep domestication by AH2A, where they were retained as a fall-back ‘walking larder’ during a period of rapid settlement expansion until AH2B. At this time, they argue, hunting declined and by AH2C herded sheep and goats became the mainstay of the food economy. Pig and cattle domestication was underway by the beginning of the 7th millennium cal. BC (Moore *et al.* 2000, 131).

2.3.3.2. Other north Levant sites (*Figure 2.3*)

Tell Halula, in the middle Euphrates valley north of Abu Hureyra, has a similar timeframe. The NISP percentage for each of the 37 levels examined shows non-linear patterns in animal exploitation (Saña i Seguí 1999; 2000). Morphometric analysis separates goats into two clusters which Saña i Seguí (1999, 2000) interprets as representing wild and domesticated individuals; she argues that the chronology of cull patterns show morphologically wild goats were managed by the early 8th millennium as an important part of the economy, but by the mid-8th millennium increasing adult culls and reliance on hunted food suggests the fully domesticated goats had become less important.

At this time (*c.* Level 9), the mid-8th millennium, morphometrically small sheep first appear in the record. Arguing that Tell Halula was outside the native habitat of sheep, their appearance records their introduction probably as domesticates (Saña i Seguí & Helmer 1999, 264). Saña i Seguí & Helmer (1999) interpreted this period as a time of crisis, where newly introduced sheep broadened and stabilised the economy. Adjusted tooth ages suggest sheep were possibly increasingly exploited for milk as well as for meat (Vigne & Helmer 2007, 27).

Kernel analysis of Halula cattle measurements identifies a reduction in the size of males but not females, *c.* 7500 cal. BC (Helmer *et al.* 2005). Although this evidence can be associated with captivity, the total numbers declined, possibly, Saña i Seguí & Helmer (1999, 139) argue, whilst herd security was being established. Oscillations in reliance on sheep and cattle up to the mid-7th mill. cal. BC might indicate (Saña i Seguí 1999) that it took time for cattle to fully established as a domestic resource.

Aswad (7800–7300 cal. BC) and Ghoraifé (7500–6300 cal. BC) are oasis sites in the Damascus Basin, between the north and south Levant. They show a clear chronology of

domestic sheep introductions diffusing from the north (Legge 1996). Towards the end of Aswad, and at the start of Ghoraifé, goat cull patterns and morphometrics suggest either targeted hunting of smaller wild females (Ducos 1993, 38), or meat production from domestic herds (Legge 1996; Helmer & Gourichon 2008); it is debated whether it was a native goat habitat (Ducos 1993; Helmer & Gourichon 2008; Legge 1996).

It is agreed that small domestic sheep were introduced at this time, and at Ghoraifé reliance on them rose to 40% NISP whilst gazelle and goat numbers dropped from 60% to 6.5% (Ducos 1993, 39). This reversed the sheep to goat ratio from 1:3 to 3:1 (Legge 1996). Ducos (1993) sees this reversal as an indicator of domestic sheep herding, whereas Legge (1996) sees the increase in sheep as a marker of intensification. It is possible that they were exploited for some milk as well as meat (Vigne & Helmer 2007, 27). The Aswad cattle are the earliest to be interpreted as domesticates, and their adjusted tooth ages suggest they were milked as well as culled for meat (Vigne & Helmer 2007, 27).

Bouqras is on the middle Euphrates outside the rain-fed agricultural zone; the evidence shows minimal agriculture and hunting (Clason 1979/80). Contemporaneous with Abu Hureyra AH2B&C, Clason (1979–80).interprets it as a second-wave village settled with domestic sheep herds.

2.3.3.3. Summary

The evidence from the early- to mid-8th millennium settlements in the north Levant suggests that arable farming and domestic herding first came together here, as mixed-agriculture villages (Peters *et al.* 2005). What might Çatalhöyük herders have learnt from this? Firstly, risk could be managed by reducing the cull of herd animals in the short term, by broadening the hunting economy, or by introducing a new domesticate. Secondly, cattle herding was entering the repertoire of the wider region. Finally, both sheep and cattle were possibly milked as well as culled for their meat.

2.3.4. Cyprus

Cyprus is the fourth area of review. Herd ungulates are not indigenous to Cyprus, but their appearance and exploitation on early sites provides zoogeographic evidence of their transportation by humans (Davis 1984; Vigne *et al.* 1999), placing important constraints on the chronology of changing animal–human relationships, and on interactions between communities (Peltenberg 2003; Vigne *et al.* 1999). The effects of island insularity highlight the historic and environmental contingency of settlement choices (Clarke 2007).

2.3.4.1. Shillourokambos (Parekklisha, Limassol)

Shillourokambos, near the Cypriot south coast, was occupied from 8534 to 7000 cal. BC (Guilaine & Briois 2001). Recent dating identifies six phases: Early A1 & A2 phases are late 9th millennium cal. BC, Early B & C are dated to the first half of the 8th millennium cal. BC and Middle A & B are late 8th millennium cal. BC (J-D. Vigne, *pers. comm.*, 16th March 2009, Wenner-Gren International Symposium).

	NISP	Caprine	Pig: fallow deer: caprine ratio	Cattle	Pig	Fallow deer
Middle B	875			0.3	20	
Middle A	3305	>50	Balanced	<1	40	30
Early B	1080	20	Deer dominate	7	25	40
Early A	225		4:2:1	5	60	25

Table 2.5
Shillourokambos NISP percentages of large meat bearing animals.
After Vigne et al. *1999; 2000*

Goats appeared in Early A Phases (*Table 2.5*) at the same time as they were first managed or domesticated (depending on precise timing) at Nevalı Çori, Gürcütepe and Aswad (Wasse 2007, 57). They were morphologically wild (though smaller than at Cafer), and male and females were at first culled equally but, in Middle A Phase, male-focused culling rapidly

increased and cull patterns suggest domestic milk and meat herding (J-D.Vigne *pers. comm.* 16th March 2009 Wenner-Gren International Symposium). Cattle were introduced with goats and, by morphometric comparison to Tell Halula specimens, were possibly domestic (Helmer & Gourichon 2008). However they declined rapidly, disappearing by the end of Early C Phase.

Sheep first appeared in Early B Phase with greatly reduced horn sizes. The LSI and individual element morphometrics of the large assemblage show that adult females dominated; Helmer and Gourichon (2008) interpreted them as fully domesticated introductions. On the Early C–Middle A Phase cusp, further size and number reduction, alongside horn-core hypoplasia (a marker of stress) coincided with goat domestication; Helmer and Gourichon (2008) suggest that goats might have replaced failing sheep stocks. Larger sheep with morphologically different horn cores then entered the assemblage, possibly introduced as new stock from the mainland. Once established, goats and sheep became the economic mainstays (Helmer & Gourichon 2008).

2.3.4.2. Other sites in Cyprus (*Figure 2.3*)

The 7500–7000 cal. BC Aceramic village of Khirokitia (LeBrun 1994), near Shillourokambos, emerged contemporaneous with Çatalhöyük's earlier phases. The hand retrieved zooarchaeological assemblage is described as meat and marrow-extraction waste from caprines, in a sheep to goat ratio that rose to 5:1 by the latest phase (Davis 1984, 149). Cull patterns suggest pigs, sheep and probably goats, were domesticated (Davis 1984, 151). It appears there were no hunting pressures until late in the sequence, when the deer NISP dropped from 45% to 10% and caprine reliance increased from 36% to 78% (Wasse 2007, 62).

2.3.4.3. Summary

Zooarchaeological research in Cyprus establishes a deep-rooted antecedent chronology of sustained herd-animal exchange networks available to Çatalhöyük herders. At the same time, the opportunities provided for local decision-making by island insularity might have infleunced Çatalhöyük decision making. In Cyprus, if interpretation is correct, cattle were not important for food or ritual, and goats were hunted whereas sheep were herded. If known to Çatalhöyük herders, these differences in human–animal relations might have influenced their own traditional practices.

2.3.5. South Levant

The fifth area is the South Levant, where the earliest interest in the 'Neolithic Revolution' stimulated excavations at Jericho and established Neolithic cultural phases (Kenyon 1957). The period contemporaneous to Çatalhöyük includes evidence of wide-scale settlement collapse in the Jordan Valley, variously associated with environmental degradation (Rollefson & Köhler-Rollefson 1989; Rollefson & Simmons 1988), climate change (Wasse 2007), and social stress (Kuijt 2000). Nomadic pastoralism is cited as a possible solution (Köhler-Rollefson 1988; 1989).

2.3.5.1. 'Ain Ghazal

At the mega-site of 'Ain Ghazal (9th to 7th millennium cal. BC), von den Driesch and Wodtke (1997) separate sheep from goats and identify a steady increase in small sheep over time (*Table 2.6*), rising from 7% in the first half of the 8th millennium to 39% during the later 8th millennium. Sample size and low sexual dimorphism prevents interpretation of management patterns, although sheep were assumed to be domestic introductions as they were not native to the area (Uerpmann 1987).

Goats declined from 93% to 61% as sheep increased (von den Driesch & Wodtke 1997). Bone-fusion data indicate 25–38% of goats were killed before 18 months, and 65–83% before 30 months, suggesting they had been domesticated from the outset (von den Driesch & Wodtke 1997, 518). Using Boessneck's (1969) sheep and goat separation criteria, Wasse (1997, 581) revises this interpretation, showing that goats remained wild throughout but might have been subject to herding experiments in the early 8th millennium (Wasse 1997, 581). The economy also included hunting and cattle management attempts (von den Driesch & Wodtke 1997, 252).

	NISP	Caprine	Sheep	Goat	Sheep: goat ratio	Cattle	Pig	Gazelle	
Yarmoukian	5102	78	39	61	2:3	5	3	7	
PPNC	4989	83	45	55	4:5	4	7	4	
LPPNB/C	2786	81	39	61	2:3	4	6	6	*von den Dreisch & Wodtke 1997*
LPPNB	4331	74	24	76	1:3	4	7	10	
MPPNB	3123	77	7	93	1:9	3	9	7	
Yarmoukian	58	33	5	33	9:1				
LPPNC	97	25	8	34	4:1				
LPPNB	21	28	35	7					*Wasse 1997*
MPPNB	256	21	29	1	1:19				

Table 2.6
'Ain Ghazal NISP percentages of large meat bearing animals.
After von den Dreisch & Wodtke 1997; Wasse 1997

2.3.5.2. Other south Levant sites *(Figure 2.3)*

Jericho goat exploitation patterns resembled 'Ain Ghazal in many respects, but poor retrieval and broad cultural phasing prevents detail associated with its collapse to be assessed (Clutton-Brock 1979). Another example, the large settlement of Yiftah'el in Lower Galilee, was short-lived, but maintained its reliance on hunted gazelle until 7500 cal. BC (Horwitz 1988). Goats were only 15% of the NISP, but a small morphometric study shows they were slightly smaller in later levels (Khalaily *et al.* 2000).

The widespread collapse coincided with the establishment of small coastal villages, such as Atlit Yam (Galili *et al.* 1993) at the end of the 7th mill. BC. Interpreted as a fishing community, Atlit Yam relied on fished resources and domestic crops, whereas goat and cattle were still wild or, possibly, in early stages of management; there were no sheep (Galili *et al.* 1993, 153).

In the late 7th millennium, herded sheep and goat (25% NISP) were introduced into the oasis site of Azraq 31 (Martin 1999, 95). Martin took evidence of continued hunting, sheep rather than goat exploitation, meat rather than milk products, and year-round on-site presence, to argue against Köhler-Rollefson's (1988) interpretation of nomadic pastoralism, and in support of Bryd's (1992) view that domestic resources had been incorporated by indigenous hunter-gatherers.

2.3.5.3. Summary

What might Çatalhöyük herder have taken from south Levant practices? Firstly, antecedent and coeval practices included fishing, hunting, early herding experiments and dependence on domestic herds. Secondly, these practices could be applied to different taxa, indigenous and introduced. Thirdly, it was possible to have a shifting balance of economic contributions from different animal procurement practices. Fourthly, different settlements could operate dissimilar economies alongside one another. Çatalhöyük herders would probably have known of the collapse of south Levant settlements, and might have understood the causes and learnt of the solutions.

2.3.6. Central Anatolia

Central Anatolia is the sixth area and at the heart of this thesis. It covers a large area of varied environments able to sustain rain-fed agriculture and within the native habitat of animal domesticate progenitors (Uerpmann 1987). Cappadocia, to the east, is a deeply

incised volcanic area where much Neolithic obsidian was sourced; Aşıklı Höyük might have contributed settlers to Çatalhöyük (Buitenhuis 1997; Esin & Harmankaya 1999).

The alluvial Konya Plain is surrounded by low hills and higher mountains, including the well-watered Lake District further west. There are 63 sites documented sites which overlap chronologically with Çatalhöyük, but only a few with published zooarchaeological assemblages (www.tayproject.org); these are mainly sited far apart on hillslopes and alluvial fans (*Figure 2.2*).

Zooarchaeological analyses from various central Anatolian sites refer to published interpretations from Çatalhöyük (e.g. Russell & Martin 2005); these are discussed in further detail in *Chapter 4*.

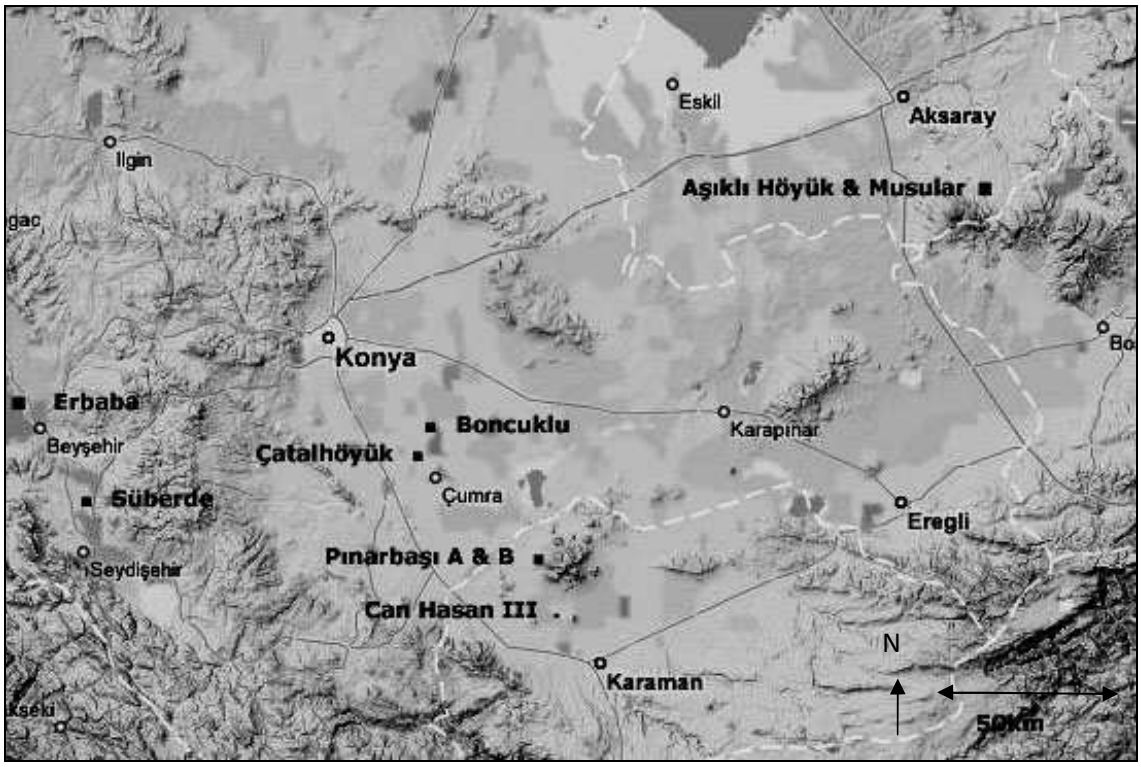


Figure 2.2.
Map of central Anatolia, showing the sites referred to in the text

2.3.6.1. Pınarbaşı A

Level	NISP	Caprine	Sheep	Goat	Cattle	Red deer	Pig
B	1913	68	52	1	17		1
A (3 levels)	173	27	12		6	3	13

Table 2.7
Pınarbaşı NISP percentages of large meat bearing animals.
After Carruthers 2003; Martin et al. *2002*

Pınarbaşı A, 25km southeast of Çatalhöyük, is a late 9th millennium cal. BC hunting camp–rock shelter with evidence of a sedentising, plant-gathering community (Watkins 1996). The zooarchaeological assemblage (Carruthers 2003) (*Table 2.7*) indicates a broad-spectrum economy focused on sheep hunting (23% NISP). Low numbers and poor taphonomy deter comment on body size or exploitation strategies. Evidence of contemporaneous caprine domestication in southeast Anatolian and north Levantine settlements, and plant cultivation at Aşıklı Höyük make it unsafe to determine whether Pınarbaşı A was a hunter–gatherer or hunter–herder camp.

2.3.6.2. Aşıklı Höyük

Level	NISP	Caprine	Sh: gt ratio	Cattle	Pig
Aşıklı 2A (late)	19,648	91	3:1	7	0.4
Aşıklı 2G (early)		84	9:2	5	6

Table 2.8
Aşıklı Höyük NISP percentages of large meat bearing animals.
After Buitenhuis 1997; 2001

Aşıklı Höyük is a large village site in the Melendiz Valley, 150km from Çatalhöyük. The Phase 2 occupation (8210–7480 cal. BC) overlaps Pınarbaşı A, making it one of the earliest Neolithic settlements in central Anatolia; it was abandoned just before Çatalhöyük was settled (Buitenhuis 1997). Its latest phase of occupation is associated with Musular, a short-lived communal–feasting area next to Aşıklı Höyük (Özbaşaran *et al.* in press).Domestic cereals and pulses contribute to the plant economy (Esin & Harmankaya 1999).

The large, well retrieved zooarchaeological assemblage (*Table 2.8*) is interpreted as food waste (Buitenhuis 1997). Caprines (*c.* 70%) dominated all phases of occupation; the sheep to goat ratio was 9:1 in the earliest Phase (2A), dropping slightly before rising again by 2B (Buitenhuis 1997, 657). Individual element size and LSI comparison to wild Cafer specimens and domestic Gritille specimens show all sheep to have been morphometrically wild (Buitenhuis 1997, 660).

Aging data indicate a targeted cull from 2.5–4 years old, interpreted as evidence of focused procurement strategies (Buitenhuis 1997, 658). However, the equal number of male and female deaths (Buitenhuis 1997, 659) is not a usual herding strategy. Foetal deaths account for 9.7% of the caprine assemblage, and 11.2% are less than a year old (Buitenhuis 1997, 656). Whilst these are not unexpected natural mortality figures (Redding 1981, 112), their on-site presence, alongside micromorphological evidence of penning deposits (Martin *et al.* 2002, 209), might indicate early attempts to breed local wild caprines in captivity. Carbon and nitrogen stable isotope values point to caprines having a limited diet, perhaps associated with close management (Pearson *et al.* 2007, 2178).

These practices remained the same throughout occupation suggesting they were imported ideas applied to local wild caprines in their native habitat, rather than being an indigenous innovation (Vigne *et al.* 1999). There is not enough evidence to determine whether cattle and pigs were domesticated (Buitenhuis 1997, 659).

2.3.6.3. Boncuklu Höyük

Recent excavations have begun at Boncuklu Höyük (end of 9th to last half of 8th millennium cal. BC), 9km from Çatalhöyük on an elevated marl rise on the Konya Plains (Baird 2006, 2007, 2008; 2009). Boncuklu potentially bridges Pinarbaşi A, Aşıklı Höyük, Canhasan III, Süberde and Çatalhöyük, however, without C^{14} dates this has yet to be clarified. Preliminary archaeobotanic analysis indicates domestic cereal crops, representing the first cultivation evidence on the Konya Plain. The zooarchaeological assemblage indicates a diverse broad spectrum of exploited wild animals, both large and small, unlike any other central Anatolian settlement.

2.3.6.4. Canhasan III

Canhasan III (7600–6650 cal. BC) is on an alluvial fan 70km to the southeast of Çatalhöyük (French *et al.* 1972), overlapping the final Neolithic phases of Aşıklı and Boncuklu and the whole Süberde occupation. Canhasan III was settled *c*. 200 years before Çatalhöyük, and was not abandoned until Çatalhöyük Level VII. The first systematic use of wet-sieving produced cultivated cereals and pulses remains, as well as wild plant remains interpreted as dung and fuel (French *et al.* 1972, 186).

Very little has been reported on the zooarchaeological assemblage from Canhasan III; there is no quantitative data, for example. Payne (in French *et al.* 1972, 188) reports that cattle were common, sheep, equids and pigs were fairly common, and that there was no indication of domestic herding. Canhasan III overlapped Çatalhöyük *c*. 800 years and, if interpretation is correct, was fully reliant on hunting.

2.3.6.5. Süberde

Süberde (7460–6770 cal. BC) was settled at approximately the same time as Canhasan III, close to Lake Suğla 100km to the west of Çatalhöyük (Bordaz 1969). Retrieval techniques did not include wet sieving and consequently the status of plant domestication is not known.

Only diagnostic elements from the large zooarchaeological assemblage (*Table 2.9*) were analysed (Perkins & Daly 1968); the majority (NISP = 81.5%) were sheep with some goats, in a sheep to goat ratio of 5.6:1. Perkins and Daly (1968, 98) used body-part representation to argue that caprines were wild and whole herds were hunted. However, age data match neither male nor female wild herd profiles as most caprines died before three years old and, in the absence of morphometric data, it is impossible to determine their domestic status (Payne 1972; Martin *et al.* 2002).

Level	NISP	Caprine	Sh: gt ratio	Cattle	Red deer	Pig	
II	11040	81.5	5.6:1	30	7	14	Perkins & Daly 1968
III				14		14	
II &III	2000	n/a	3.7:1				Arbuckle 2008a

Table 2.9
Süberde NISP percentages of large meat bearing animals
Afte Perkins & Daly 1968; Arbuckle 2008a.

By combining morphometric and age data in a Süberde sub-sample, Arbuckle (2008a, 228) shows there were equal numbers of males and females culled. All caprines (using LSI) were as large as those from Aşıklı (Arbuckle 2008a, 227), although the astragali size fell between Aşıklı and Çatalhöyük specimens. Alhough different from Aşıklı Höyük, Arbuckle (2008a) suggests that Süberde caprines were possibly domesticated, but remained larger than Çatalhöyük caprines as the setting was central to their native habitat, and as the small settlement size would have been less intensely anthropogenic, and inbreeding with wild caprines more likely.

2.3.6.6. Erbaba

Erbaba was coeval with Çatalhöyük later Levels VIII to II, 75km to the west near Lake Beyşehir (Bordaz & Bordaz 1982). Dry sieving and flotation revealed domestic grains and pulses. Bordaz and Bordaz (1982) report Perkins and Daly's assessment that cattle and sheep were domesticated, and that cattle increased and sheep declined over time (*Table 2.10*). In later levels sheep were often slaughtered as older animals, possibly indicating a wool economy. However the absence of supporting data is a concern (Martin *et al.* 2002).

Arbuckle's (2008b) reassessment of the assemblage separates sheep and goats. The NISP indicates a greater reliance on sheep, which were most heavily culled in their first year (45% at 6–12 months), whereas small goat numbers were consistently culled later (29% at 6–12

Level	NISP	Caprine	Sheep	Goat	Sh: gt ratio	Cattle	Pig	Red deer	
I	15,000	73			4.6:1	27			Bordaz & Bordaz 1982
III		95				5			
I		73	23.6	6	4:1	5.6		6.4	
II	3933	71	23.9	5.6	4:3	8.9	10	7.4	Arbuckle 2008b
III		84	26.0	3	7:3	4	5	3.8	

Table 2.10
Erbaba NISP percentages of large meat bearing animals.
After Bordaz & Bordaz 1982; Arbuckle 2008b

months) (Arbuckle 2008b, 350–353). As male sheep were selected for culling, Arbuckle (2008b) proposes there was meat herding in the early levels, whereas goats, culled older throughout, might have been a small herd kept for their milk and hair.

Caprines were culled older in later levels (35%, increasing to 52%, over two years old), however there were increasing numbers of very large sheep astragali alongside others that

fell between the Aşıklı and Çatalhöyük size ranges (Arbuckle 2008b, 352). The sheep samples fell into multiple discrete size clusters, indicative of both hunting and domestic herd exploitation, and the cull profiles reflect an increase in hunting older sheep over time (Arbuckle 2008b, 358).

The caprine to cattle ratio at Erbaba decreased significantly throughout occupation, cattle were small from the outset with no diminution over time, and their cull focused on juveniles that were butchered on site (Arbuckle & Makarewicz 2009, 672–679).As red deer data discount a Bergmann effect, Arbuckle & Makarewicz (2009) propose that, alongside continued auroch hunting, domestic cattle herding was in place from Erbaba's foundation.

2.3.6.7. Pınarbaşı B

Pınarbaşı B was in use at the very end of the Çatalhöyük Neolithic occupation, overlapping by a possible 200 years (Watkins 1996). Morphometrically small sheep make up 65% of the NISP, 75–81% were culled under three years old (*Table 2.7*), and there were penning deposits (Carruthers 2003, 262). This is interpreted as domesticates herded for meat (Carruthers 2003, 205). The BPR points to on-site consumption of red deer (Carruthers 2003, 266), whereas caprine and wild cattle meat-bearing limbs were taken elsewhere (Carruthers 2003, 213). Seasonality evidence, based on ageing data, tentatively indicates late spring seasonal occupation (Carruthers 2003, 267); possibly Pınarbaşı B was a camp for seasonal herding activities.

2.3.6.8. Summary

In central Anatolia, before Çatalhöyük was founded, there was remarkable economic variation and a range of animal exploitation strategies, all of which might have been known to Çatalhöyük settlers, or might have contributed to a complex settlement ancestry. The variety of economies included broad-spectrum hunting with some domestic crop cultivation,

focused wild sheep hunting with domestic crop cultivation, wild cattle and caprine hunting with domestic plant cultivation.

The number of Neolithic sites more immediately antecedent and local to Çatalhöyük might have been due to incoming migrations (Özdoğan 1998), bringing domestic caprine herds from elsewhere to an area where there were already settled hunting communities; both economic systems might have lived side by side at first, providing alternative economic models.

	Aşıklı Höyük Sheep and goat separated	*Süberde* Sheep/goats combined	*Erbaba* Sheep and goat separated
Size	Morphologically wild	Larger than Çatalhöyük, a little smaller than Aşıklı Höyük	Larger than Çatalhöyük, a little smaller than Aşıklı Höyük, getting larger later
Cull ages	2.5 to 4 years Plus perinatal deaths	1 to 3 years 2 yr. peak	1-2 years for sheep, a little older for goats. Both older in later levels
Sex cull patterns	No selection	No selection	Could not be analysed
Interpretation	*Imported ideas trialled in early captive breeding of wild sheep*	*Early herding in less anthropogenic setting than at Çatalhöyük*	*Domestic sheep for meat and a few goats for milk or hair. Hunting and cattle herding increasing, sheep herding declining.*
Qualifications	Penning evidence explains perinatal deaths in assemblage	LSI show same size as Aşıklı Höyük, only astragali show difference	Cull age changes probably reflect more hunted animals.
		Cull profiles could be intensive wild management	Cull age differences might reflect different strategies for sheep and goat
	Equal sex ratios do not fit herd security	Equal sex ratios do not fit herd security	Sex ratios not analysed
		Cull age rather young for herding	Phasing and dating not secure
Reference	Buitenhuis 1997	Arbuckle 2008a	Arbuckle 2008b; Arbuckle *et al.* 2009

Table 2.11
Summary of herding practices at Aşıklı Höyük, Süberde and Erbaba

Different settlements adjusted their economies by increasing reliance on caprines, by separating sheep and goat product goals and by changing their reliance on cattle and on hunting. In particular, different patterns of caprine exploitation emerged in the settled villages of Aşıklı Höyük and Süberde, then later at Erbaba, all spatially and chronologically close to Çatalhöyük (*Table 2.11*).

Sheep were the earliest domestic herd animals in the central Anatolian Neolithic. The presence of wild sheep in their native habitat would have given Çatalhöyük herders opportunity to re-stock and to study seasonal feeding, breeding and movement behaviour in localities suitable for domestic herding. There were possible connections between larger settlements and 'satellite' communities. The evidence suggests that pigs were not important to the Çatalhöyük economy in contrast to many southeast Anatolian settlements. The Çatalhöyük herders might have known why this was so, but the potential to initiate local management could have been in their herding repertoire. The ritual importance of wild cattle at Aşıklı Höyük suggests an ancestral link with Çatalhöyük, and might explain why the first evidence of their increased Central Anatolian exploitation at Erbaba was long after the earliest evidence of their management elsewhere in southwest Asia.

2.4. Conclusion

Aşıklı Höyük evidence suggests the central Anatolian Neolithic paralleled the spread throughout the Fertile Crescent. However, the variety in settlement economies (*Figure 2.3*) illustrates the 'selective use of what we term Neolithic techniques, and reminds us that cultural adaption evolves in idiosyncratic ways' (Joukowsky 1996, 73), where 'each [*economy was*] unique to its own geographic and sociocultural context' (Arbuckle 2008a, 232).

In order to reveal and interpret such unique practices in early herding economies it is necessary to collect 'more specific and precise data … such as seasonality, mobility, and foddering.' (Arbuckle 2008a, 231). This thesis presents such data, but first reviews the material culture and economy of the case site, Çatalhöyük in *Chapters 3* and *4*. The choices made by Çatalhöyük herders are compared to the herding practice repertoire established in this chapter, and ways in which the herders' socio-cultural context might have influenced decisions is explored.

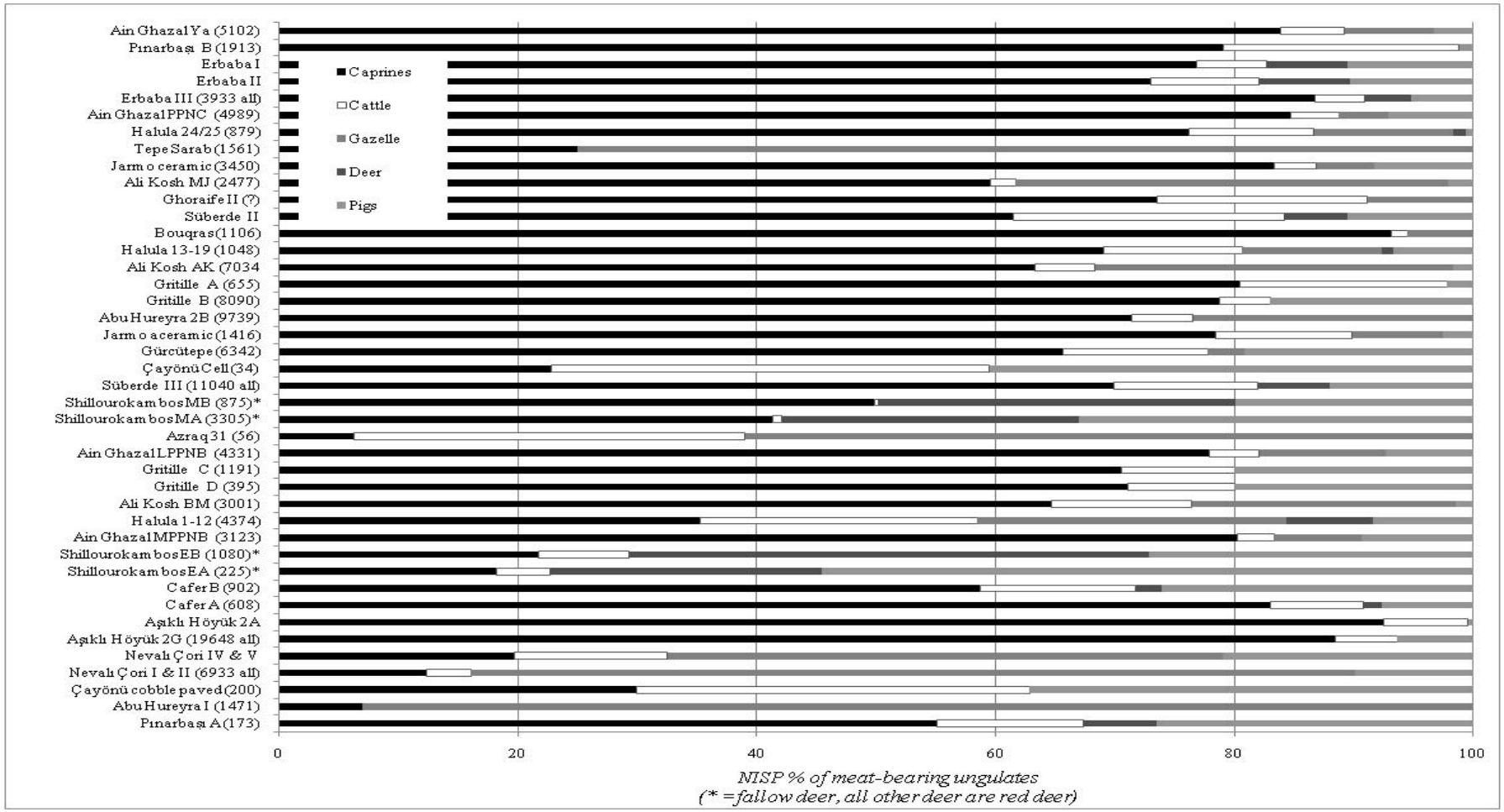


Figure 2.3
Chart of NISP percentages of meat bearing ungulate for all settlements referred to in Chapter 2, arranged in a broad temporal sequence (earliest at the bottom)

CHAPTER 3. THE CASE-STUDY SITE: ÇATALHÖYÜK

3.1. Introduction

The thesis proposes that herding practices at Çatalhöyük would have been selected from a wide body of herding knowledge (*Chapter 2*), and that this selection would have highly contingent on social, ritual and environmental factors. In this chapter the case-study site, Çatalhöyük, is introduced and the current interpretation of its material culture outlined. The aim is to describe the settled context in which Çatalhöyük herders might have lived.

The evidence of settlement distribution (Baird 2005) suggests that Çatalhöyük stood alone on the Konya Plain and its middens show that extensive domestic sheep exploitation took place on site (*Chapter 4*). Consequently, it is possible to argue that Çatalhöyük was a significant centre for herders; its material culture and socio-ritual life were the herders' world, and in turn the herders' sphere of activity was an element of the social life of the settlement.

This thesis asks how the role of herders was integrated into other economic and social spheres at Çatalhöyük. Even if herding had not been a specialised role it is likely that certain tasks would have been more highly valued than others. It is largely within the settlement that the position, status and work patterns associated with herding would have been negotiated with other roles demanded of each inhabitant.

It is likely that herding practices intersected with practices relating to other aspects of the material culture. Possible trends of influence might have derived, for example, from

changing raw material sources. In discussing the Çatalhöyük material culture, this chapter summarises associated spatial, temporal and landscape-use patterns.

3.2. Çatalhöyük site and excavation

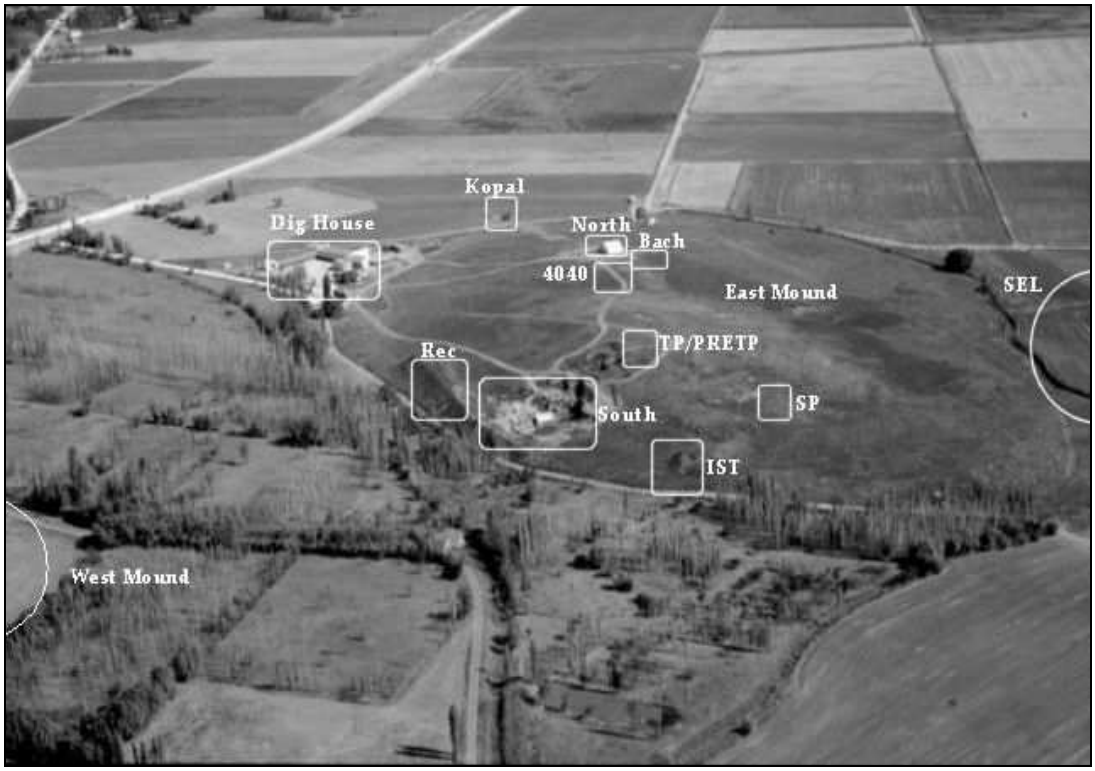


Figure 3.1.
Aerial photo of Çatalhöyük East and West showing surrounding Konya Plain, and position of excavation areas.
Marciniak 2007, 283, Fig. 2

Çatalhöyük is situated in the southwest sector of the Konya Plain in central Anatolia, 48km south of Konya and 13km north of Çumra (Latitude 37.30N, Longitude 33.00E, altitude *c.*1000masl) (Roberts 1983). The Çatalhöyük tell consists of a Neolithic settlement on the East Mound and a Chalcolithic settlement on the West Mound (*Figure 3.1*). The East Mound (hereafter Çatalhöyük) is one of the larger Early Neolithic archaeological sites in southwest Asia, covering *c.* 13ha and reaching a depth of 17.5m (Pollard *et al.* 1996).

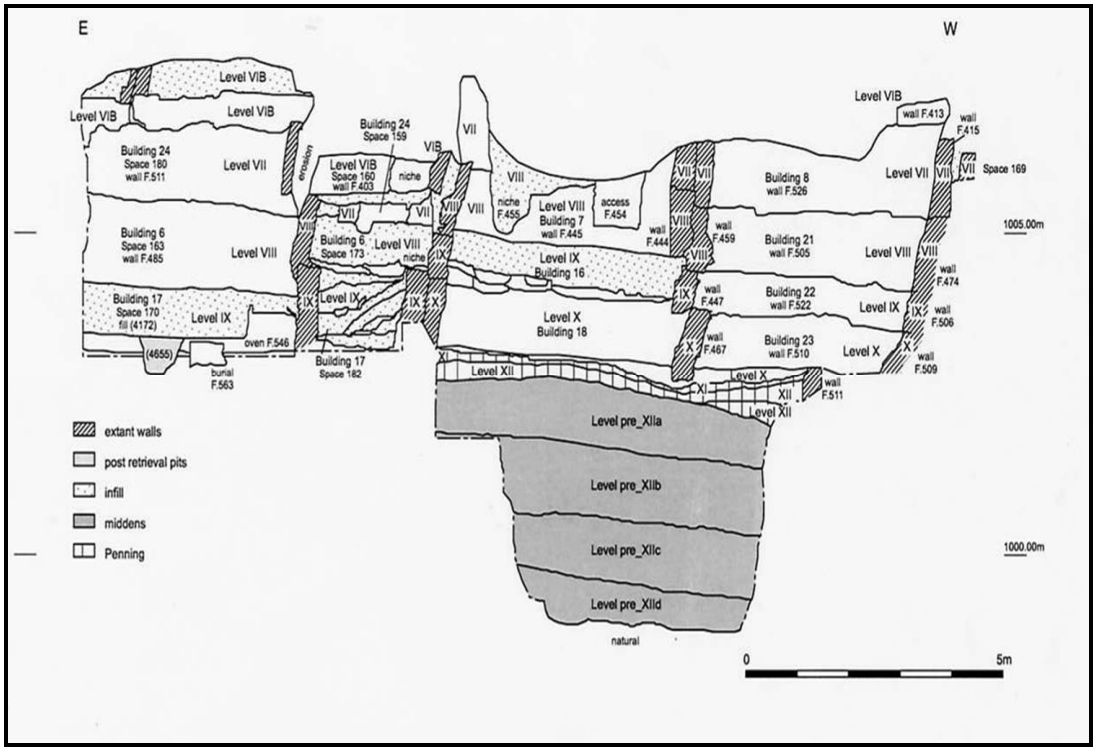


Figure 3.2
Composite section prepared by S. Farid and D. Lees for the sequence of levels in the South Area of Çatalhöyük.
Hodder 2006, 116, Figure 48

Çatalhöyük was first excavated in the 1960s (Mellaart 1962; 1963; 1964; 1966; 1967). A system of levels based on building stratigraphy was established, but excavation did not reach the base of the tell (*Figure 3.2*). The site was re-opened in 1993 for a further thirty-year period of excavation (Hodder 1996) that aimed to re-establish and extend Mellaart's work, through single-context analysis of the fine stratigraphy, and the use of a suite of scientific analyses of the archaeological record (Hodder 2000).

The Çatalhöyük material culture has been extensively researched and published by a range of specialists, providing a large body of data and interpretation. The central core of evidence used in this chapter rests in five volumes covering the 1995-1999 seasons (Hodder 2000; 2005a, b, c; 2007), which focus on a representative selection of Units from Levels XIIE–VI; a sixth volume reassesses evidence from the Mellaart excavation (Hodder 1996). Hodder's

book ‘The Leopard’s Tale’ (2006) and the Project’s archive reports (www.catalhoyuk.com) provide the basis for discussion on later levels that were excavated more recently.

3.3. Chronology of Neolithic Çatalhöyük

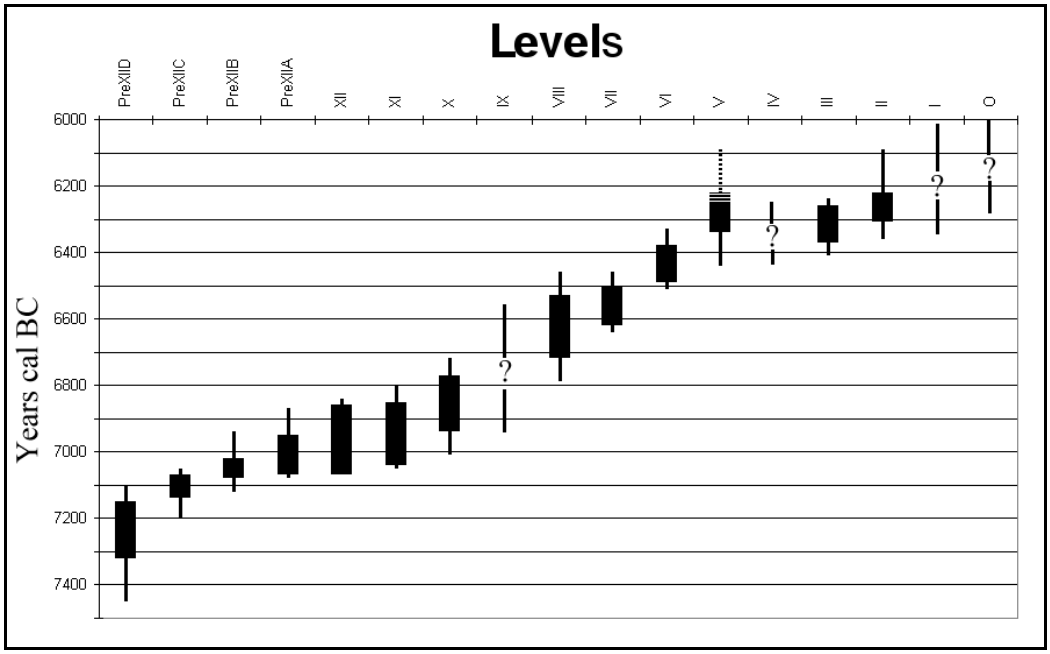


Figure 3.3
Radiocarbon determinations from the Çatalhöyük East sequence.
Hodder 2005a, 8, Fig 1.6

The occupation of Çatalhöyük lasted continuously for *c.*1200 years, between 7400–7100 and 6200–5900 cal. BC (*Table 2.1*). Eighteen occupation levels in the South and TP Areas have been stratigraphically identified and AMS dated (Cessford 2001) (*Figure 3.3*); other excavation areas (Bach, North, 4040, IST) are linked to these levels by pottery and tool typologies. Pre-XIIA–E Levels are Aceramic, Levels XII–VI are early Ceramic and Levels V–I are late Ceramic. To date, only settlement edge middens and activity areas have been revealed in the Aceramic period, and consequently discussion of the built environment and *in situ* artefacts is limited to the Ceramic Neolithic settlement.

The Çatalhöyük levelling system is presently under review (Farid 2008) and a revised system, to be introduced in 2012, will be linked to an updated Bayesian dating sequence

(Bayliss & Farid 2008). In this chapter assigned levels are taken from the excavation database, updated in October 2009.

In the following sections the evidence from Çatalhöyük is reviewed, and brief comparison is made to selected antecedent and coeval practices in the Neolithic of southwest Asia, cited in Chapter 2 and *Appendices 1-6*.

3.4. Settlement plan and architecture

Excavation and surface collection at Çatalhöyük suggest that different parts of the mound came into use at different times, but at its largest, between Levels VIII and VI, much of the mound was occupied (Düring 2007), reaching a modelled population between 3500 and 8000 (Cessford 2005b).

Düring's (2005) comparison of Çatalhöyük early Ceramic Levels XII–VII with Aşıklı Höyük Levels 2A–2G (Late 9th millennium) discusses similarities in settlement layout. Firstly, the single-storey, rectilinear, mud brick buildings generally had the same orientation and construction footprints, such that a sequence could span a considerable period; one Çatalhöyük sequence spanned 400 years (Hodder 2006, 127). Secondly, buildings abutted others in agglutinative, densely-packed neighbourhood groups of 30 to 60; any spaces were usually filled with midden (Hodder *et al.* 2007). Thirdly, buildings were entered by a ladder through the roof; movement was probably over the roof-tops. These similarities were widespread in southwest Asia, and included central Anatolian settlements that overlapped the earlier occupation of Çatalhöyük (e.g. Canhasan III) and also the later occupation (e.g. Erbaba). However some, including Boncuklu, maintained earlier, semi-subterranean ovoid forms, possibly into the second half of the 8th millennium cal. BC.

Çatalhöyük architecture in Levels XII–VII differs in a key respect from Aşıklı Höyük (Düring 2005, 2007). Aşıklı Höyük has large monumental structures and spaces as well as its associated monumental area of Musular, whereas at Çatalhöyük there is no evidence of such differentiation (Hodder 2006, 98); as will be discussed below, social and ritual organisation at Çatalhöyük appears to have been focused on the house. Monumentality was a particular feature of south-east Anatolia antecedent to Çatalhöyük (e.g. 10th mill. BC Göbekli Tepe and 9th and early 8th mill. BC Hallan Çemi and Nevalı Çori), and was retained in a few late 8th millennium settlements such as Gürcütepe and Çayönü. Monumentality evidence in the Levant includes 9th millennium Jericho, 8th millennium Halula and early 7th millennium 'Ain Ghazal.

One of the remarkable features of Çatalhöyük was its reiterative practices, most often focused on the 'house' and most clearly seen in Levels XII–V (Hodder 2006, 137). Some buildings with a longer sequence of rebuilding, those Hodder has termed 'history houses', had slightly more internal elaboration (Hodder 2006, 153–61). They are interpreted as having been central to organised neighbourhoods (Düring & Marciniak 2005, 179), which possibly housed clusters of different contributory communities (Baird 2006).

From Level V onwards, Çatalhöyük was less-densely built, some houses were more spacious with two-storeys and further internal divisions (Düring 2005). Düring and Marciniak (2005) suggest that neighbourhoods were no longer emphasized and household based social units were emerging. New central Anatolian settlements might have reduced population pressures at Çatalhöyük, removing the need to organise into sub-groups (Baird 2006).

The walls of the houses were primarily built of mud brick with timber, reed and mud roofs (Cutting 2005). Dark silty clay was used for bricks up to Level IX, and then largely replaced by buff-coloured silty material by Level VII; all were locally sourced (Love 2010). Preliminary archaeobotanical evidence from burnt brick (Bogaard *et al.* 2008; Ryan 2010)

shows reeds, grasses and crop processing chaff (but not straw) were used as temper (*Figure 3.4*). Evidence of timber use may be seen in post-retrieval features, roof collapse stratigraphy and charcoal. Throughout the occupation, timbers were predominantly oak (Fairbairn *et al.* 2002) with a slight reversal in favour of riparian and xeric species sources in Level Pre-XIIA (Asouti & Hather 2001). Timber wall frames declined throughout the occupation and were virtually absent by Level II (Asouti 2005).

This pattern of building construction is repeated throughout the 8th millennium of southwest Asia, even where brick material was hard to source, as at Aşıklı (Duru 2002). However, stone, wattle and daub, and slab brick were also common. Timbers and reeds were commonly used for roofing in southwest Asia (Fairbairn *et al.* 2002).

Figure 3.4
Cross-section of a burnt mudbrick showing whole silica skeletons of plant parts. Çatalhöyük 2007 archive report, 205, Fig.147

3.5. Internal house design

Çatalhöyük buildings appear to have been household dwellings accommodating an estimated five to ten people (Cessford 2005b). Inside, the space was divided into one, and sometimes two, main rooms, with subsidiary smaller storage spaces (Düring 2007) (*Figure 3.5*). The

arrangement was somewhat codified in a further example of reiterative practice, although slight differences contribute to interpretation of a household scale of construction (Hodder 2006). This internal design is common to permanent settlement first seen slightly earlier in the 2nd half of the 8th millennium in southwest Asia, and may be contrasted to simpler one-roomed structures lacking platforms, ovens and storage seen earlier at Aşıklı Höyük and in early Ali Kosh, and in contemporaneous settlements with no internal hearths such as Süberde.

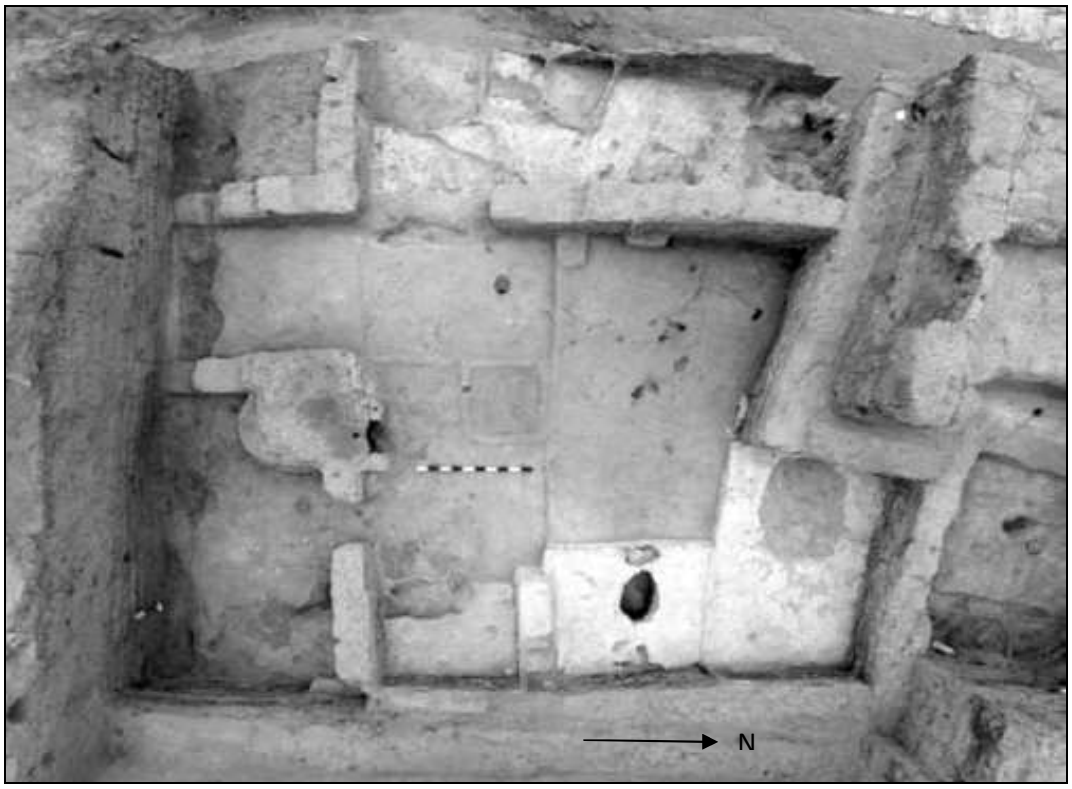


Figure 3.5
Overhead view of Building 65, South Area.
Çatalhöyük 2006 Archive Report, 3, Fig.2

3.5.1. Dirty areas

In Çatalhöyük buildings, a dirty space to the south commonly contained an oven at the foot of the entry ladder, storage bins, and evidence of cooking and craft activities (Farid 2007a) such as debitage from chipped stone and bead production, numerous buried caches of

obsidian (Carter *et al.* 2005a) ground stone (Baysall & Wright 2005), pottery (N. Yalman, *pers. comm.*, 28th July 2009) and clay balls collections (Atalay 2005). In Level VII a cattle scapula was specially deposited (Russell & Meece 2005).

As buildings were usually cleaned on planned abandonment, the *in situ* record is largely restricted to permanent structures, but more complete records from burnt buildings can provide further detail. In their spatial analyses of the burnt remains in Building 52 (4040, VI–V), Twiss *et al.* (2008) and Bogaard *et al.* (2009) find that dry plant foods, and animal bones and obsidian blades used in tool production, were kept in bins and perishable containers in the storage areas, whereas cattle horn cores and a bucranium were placed in the clean area (Twiss *et al.* 2008). It is suggested that the contradictions between household and communal activities were managed by privately stored every-day goods, and publically accessible feasting remains (Bogaard *et al*. 2009; Twiss *et al.* 2008).

3.5.2. Clean areas

The north space of the buildings was usually clean, with platforms around the edges occasionally functioning as a repository for human burials. The contextual association of burials with wall painting, reliefs and installations is a central component to understanding the clean areas. It is evident that they held a special place in social and ritual life at Çatalhöyük, in contrast with the day-to-day of the dirty area.

A remarkable feature of the clean areas was the frequency of re-plastering and whitewashing: Düring (2007) cites 450 layers in one example. In Building 5 (North, VIII–VII) micromorphological evidence of seasonal soot suggests annual re-plastering with bi-monthly whitewashing (Matthews *et al*. 2006). Throughout occupation, a base layer of local clays was used in both clean and dirty areas, with a second finishing coat of local marl in the later (Stevanović & St. George 2005). Mud plastering was common practice in the Neolithic

of southwest Asia, although the marl coating was usually absent; this was probably a local resource unique to the Çatalhöyük environment.

In Levels VI and earlier, walls were occasionally painted red or with simple red-and-black geometric patterns. This style continues in the upper levels but there is evidence of increasingly complex painting. Figurative paintings, such as the bull-leopard in Level IX and vultures in VIII and VII, were followed by scenes, culminating in the hunting scenes of Level V onwards (Last 2005b). The narrative character of these later scenes depicted a range of wild animals being taunted by hunters who were usually male (Russell & Meece 2005). The most remarkable aspect of wall paintings is that they were covered with plaster, possibly within months of completion (Matthews *et al.* 2006), in contrast to the preservation, re-plastering and occasional curation of the reliefs and installations (Last 2005b).

Installations found in clean areas throughout Levels VII and VI (Russell & Meece 2005) include plastered or painted benches and pillars mounted, most commonly, with plastered wild cattle bucrania and horns (Last 2005b) (*Figure 3.6*); the animals used in installations were rarely represented in paintings (Russell & Meece 2005). In Level VIII there were reliefs of leopard pairs (Russell & Meece 2005) and splayed bears were commonly represented. Less spectacular, and often hidden in plastered niches, were jaws and claws of smaller wild animals (Last 2005b). On building abandonment, zoomorphic installations often had their heads and feet removed (Russell & Meece 2005).

The paintings at Çatalhöyük are unparalleled in southwest Asia, where painting was restricted to floors and occasional geometric designs. Exceptions include crane paintings at Bouqras and figurative painting on the floor at Halula. The installations were also unique, although they have resonances with earlier reliefs in southeast Anatolia and earlier Zagros sites. In central Anatolia, only Canhasan III has a similar arrangement of platforms, and

preliminary evidence from Boncuklu suggests parallels in its wild animal installations (L. Martin, *pers. comm.*, 15th September 2009).

Figure 3.6
In situ *cattle bucrania in Building 52, Area 4040.*
Çatalhöyük 2005 Archive Report, 4, Fig. 5

Hodder (2006, 53) discusses the dirty and clean areas as, respectively, spheres of domestic production and of exchange and ancestry, but the frequent evidence of how one section of the material culture references another, how some are long-lasting and others ephemeral, and how practices of use, deposition and discard are highly codified, suggests it is necessary to look beyond space divisions to investigate the social life and belief systems of the Çatalhöyük inhabitants. Hodder (2006, 53) argues that the rules allow us to approach an understanding of the sphere of community that surely existed to organise events such as hunts, feasts, harvest or land access.

3.6. Tool and ornamentation artefacts

A wide range of artefact classes are rarely, if at all, found *in situ,* and have been retrieved from middens and in re-deposited fills and layers often associated with different stages of building construction. Foundation opening and building closure followed certain patterns throughout the occupation (Farid 2007a); such codified practices were common in the Neolithic of southwest Asia (Hodder 2006, 132). There appears to be a highly repetitive distinction between things that are 'of the house' and that consequently remained there on abandonment or were curated to new houses or grave goods, and those that might be in the house during its occupation but were discarded after use (Hodder 2006, 59, 129–131).

The following review of the Çatalhöyük artefacts – the tool-kits and ornamentation – restricts itself to spatial and temporal patterns of procurement, manufacture, debitage, use and discard that might potentially be relevant to later interpretation of the spatial and temporal patterns of herding practice.

3.6.1. Chipped stone industry

The Çatalhöyük chipped stone assemblage is 95% obsidian with very little flint; there were multiple *chaîne opératoires* and, in most, the obsidian and flint technologies paralleled one another (Carter *et al.* 2005a). Retouching and use-wear evidence is indicative of the general use of chipped stone, but only particular signatures stemming from projectile use, wood chopping in Pre-VII Levels, and cereal and wetland plant harvesting allow specific use to be proposed (T. Carter, *pers. comm.,* 29th July 2009).

The main picture is one of sourcing and manufacture at a household level. In Pre-XIIBD, Epi-Palaeolithic micro-blades and Aceramic scrapers were evident, as was the greatest use and range of flint (Carter *et al.* 2005a). From Pre-XII onwards a local industry of non-standardised blades and flakes from crudely made cores ran parallel to industries that used

pre-prepared cores and their waste flakes (Carter *et al.* 2005a) (*Figure 3.7*). There was careful curation of bipolar blades, replaced after Level VIB with unipolar forms (Carter *et al.* 2005a).

Figure 3.7
Obsidian bullet-shaped pressure-flaked prismatic blade cores.
Çatalhöyük 2006 Archive Report, 249, Fig.155

Flint sources are hard to trace as they are associated with limestone which is widespread around the whole Taurus Mountain arc, and as their physical signature can vary within one piece (Carter *et al.* 2005b). Obsidian in Levels IX–III was sourced from outcrops in Cappadocia (Carter *et al.* 2005b). Of these outcrops, Göllü Dağ East obsidian was sourced from at least Level X until Level VII, after which the source changed to Nenezi Dağ coinciding with the ascendance of the unipolar pressure-flaking industry (Carter *et al.* 2005b).

There was a brief early period when the Çatalhöyük chipped stone industry resembled that of other Central Anatolia sites, but by Pre-XIIC and D the industry became influenced by, and part of, the whole southwest Asian sphere (Carter *et al.* 2005a). Cappadocian-sourced obsidian appeared in the early 9th millennium and became widespread over the following

two millennia (Carter *et al.* 2005a; b). Close to Cappadocian sources, highly specialised core preparation was effected in the obsidian workshop at Kaletepe, coinciding with the disappearance of on-site core reduction in much of southwest Asia (Carter *et al.* 2005b). Aşıklı Höyük, however continued to produce its own reduced cores and tools with no apparent links to Kaletepe (Carter *et al.* 2005b). The closest confirmed link to Çatalhöyük is a pair of inscribed points from Canhasan III, but trends from the Cilician coast, and Pınarbaşı A and Aşıklı Höyük, suggest multi-derivations (Carter *et al.* 2005a).

3.6.2. Ground stone

Larger ground stone slabs are associated with food production and smaller handstones with craft activities (Baysal & Wright 2005). The nearest volcanic source to Çatalhöyük, suitable for milling stones, is 40km distant on Mount Karadağ. The absence of large pieces, and evidence of extensive wear and re-use, suggests milling stones were highly curated (Baysal & Wright 2005). Local sandstone used for smaller abraders, drills and mace-heads, and marble used to make polishing slabs, were less curated (Baysal & Wright 2005).

There is no evidence of workshops at Çatalhöyük but debitage suggests on-site manufacture in small-scale household production (Baysal & Wright 2005). Most ground stone objects were discarded in middens but some were cached in dirty areas; a mortar-and-pestle set in front of a cattle-horn installation in the burnt Building 52 (4040, VI–V) is a rare example of ground stone in a clean area (Baysal & Wright 2005).

There is no evidence of temporal changes in materials, manufacture or use during the occupation of Çatalhöyük (Baysal & Wright 2005). Ground stone industries across southwest Asia showed a huge expansion associated with settlement and farming (Baysal & Wright 2005).

3.6.3. Bone tools

Worked bone can be divided into tools and more ornamental forms, although Russell (2005, 340) argues for a categorisation by labour costs and concern with curation. Caprine metapodia provided the most valuable material because of their qualities and relative abundance, but cattle scapulae and deer antlers were also valued for certain tools.

Points represent nearly 50% of the total worked-bone assemblage and subtle differences indicate household based manufacture (Russell 2005). Around Level VI points were increasingly made by groove-and-split technology which was labour intensive but conserved material better (Russell 2007a; 2008). Wear suggests that most points were hafted and then used for piercing soft organic materials, whilst others were suited for weaving and net-making (Russell 2005).

A second set of tools is associated with building work. The appearance of chisels around Level IX coincided with soft antler-made hammers. The hammers decreased around Level VI–IV coinciding with new antler pressure flakers and the introduction of new lithic techniques (Russell 2007a). The wide variety of bone tools also included fish-hooks and harpoons, and an increased number of polishers for non-tempered pottery in Level VIII (Russell 2005, 2007a, 2008).

Bone tools have always been used by humans, as attested by their ubiquity in the southwest Asian Epi-Palaeolithic and Neolithic, their form and variety changing with the demands of new industries.

3.6.4. Pottery

There is very little pottery at Çatalhöyük; nevertheless it is amongst the earliest known in southwest Asia (Last 1996), first appearing in South Area middens in Level XI (Last 1999).

The pottery tradition was simple and conservative, displaying variation typical of household based manufacture (Last 2005a). All pottery was discarded in midden and fills (Last 2005a) with only one example of *in situ* pottery cached in a plaster-lipped basin near an oven (N. Yalman, *pers. comm.,* 28th July 2009).

Pottery made from local clays constituted the assemblage up to Level VI (Last 2005a) and was tempered with organic remains such as cereal straws and seeds (Last 2005a). Rare early experimentation using non-tempered clay with a higher mineral content became more commonplace between Levels VI and VIII and, during Level VII, new forms were introduced (Last 2005a). In Levels V–IV further variety emerged; some were simply decorated; some had anthropomorphic and zoomorphic reliefs (N. Yalman, *pers. comm.,* 28th July 2009); and some pieces were very small which, Hodder (2006, 233) suggests, might have been mobiliary forms that took personal expression outside the buildings and extended the life-time of gifting.

The early pottery technology and form was homogeneous when it first appeared at Çatalhöyük, indicating its introduction from elsewhere (Last 2005b). The later pottery fabric could withstand high temperatures and its appearance coincided with the disappearance of clay balls, suggesting that use shifted from storage to cooking; some sherds had lipid residues inside (Copley *et al.* 2005). The change in fabric might have involved sourcing the clays in more distant areas (N. Yalman, *pers. comm.,* 28th July 2009), although Doherty (2010, 21) argues for the nearby availability of suitable Pleistocene alluvial sediments.

Throughout southwest Asia there is a horizon of early pottery dated to *c.* 7000 cal. BC, matching Çatalhöyük Level XII dates of 7000–6900 cal. BC, and the change to non-organically tempered fabrics throughout southwest Asia took place between 6400–6000 cal. BC, slightly later than Çatalhöyük Level VII at 6600 cal. BC (Last 2005b). Canhasan III remained Aceramic until the mid-7th millennium, and Cypriot settlements remained

Aceramic until the end of the 6th millennium. In other parts of southwest Asia pottery was a more important part of the material culture (N. Yalman, *pers. comm.*, 28th July 2009); Ali Kosh, Zagros, has examples of decorated vessels early in its sequence.

3.6.5. Clay balls

Clay balls, 6–7cm in diameter, were an essential component of the earlier Çatalhöyük toolkit. They were made from a silty fabric with natural mineral inclusions giving them non-crumbling, non-porous qualities (Atalay 2005). The fabric might have been sourced from the River May headwaters, demanding focused journeys of 30–40km, and suggesting the fabric was highly prized (S. Atalay, *pers. comm.*, 14th July 2009), although, as with the pottery, Doherty (2010, 21) the material might have been local to Çatalhöyük.

Analysis of the *in situ* and re-deposited contexts shows a marked temporal change. Clay balls were found in ovens in Level X; by Level VIII some balls were *in situ*, some re-deposited, and one group, in Building 5 between wild goat horns, formed a special deposit; by Level VII–IV almost none were found *in situ* (Atalay 2005). The coincident disappearance of clay balls with the introduction of fire-proof pottery suitable for cooking suggests clay balls were used as pot-boilers (Atalay 2005).

Clay balls are rare in southwest Asia and have only been mentioned in 8th millennium Aswad and then Ghoraife, and in 7th millennium Jarmo.

3.6.6. Matting and baskets

In undisturbed contexts, phytolith residues from plants reveal coiled and platted matting on floors in dirty areas and around burials, and basket impressions on clay balls (Wendrich 2005) and special deposits (Ryan 2010). The phytoliths mainly derived from robust wetland rushes and sedges and are likely to have grown locally; more fragile cereal stems such as barley straw were not used until the latest levels (Ryan 2010). The Çatalhöyük basketry and

matting assemblage has its roots in the Epi-Palaeolithic and is common to settlements throughout the Neolithic of southwest Asia (Ryan 2010).

3.6.7. Spindle whorls

Spindle whorls are absent from the Çatalhöyük Neolithic assemblage but are found in 8th millennium Aswad, and 7th millennium Jarmo and Ali Kosh later levels. As they might indicate exploitation of sheep for their wool their absence in Çatalhöyük is of note.

3.6.8. Figurines

Figurines are frequent in the Çatalhöyük assemblage and were usually made from locally sourced clays (Meskell 2007). As they were roughly made and usually broken, sometimes deliberately, their identification is difficult (Russell & Meece 2005). Meskell (2007) warns of constructing false categorisations as there might have been a deliberate blurring of taxa and gender (Meskell 2008).

Hamilton (2005a) distinguishes between minimalistic gender-neutral humanoid forms, some with detachable heads (Meskell 2007), and more representative human figurines, sometimes gender specific. The latter group includes the obese seated woman flanked by leopards found in Building A.II.1 (Last 2005b). Zoomorphic forms are usually quadrupeds (*Figure 3.8*), including sheep, and cattle horns account for 75% (Russell & Meece 2005). The identifiable forms contrast with the wild species focus seen in paintings (Meskell 2008).

Çatalhöyük figurines are almost all found in household middens and reworked construction contexts and appear to be disposed of in similar ways to other clay objects, food and tool waste (Meskell *et al.* 2008). There are examples of deliberate deposition, such as a large female figure in the demolition deposit of Building 6 (South VIII) and a stone figurine possibly associated with the closure of Building 49 (4040, VI–V) (Meskell 2007).

Throughout southwest Asia from the end of the 9th millennium figurines are similarly ubiquitous (Last 2005b), however only anthropomorphic forms are found at Gritille and only zoomorphs at Aşıklı Höyük. At Aswad there are large female figurines similar to those at Çatalhöyük. Phallomorphic forms might reference earlier monumental structures at Göbekli and Nevalı Çori (Meskell 2008).

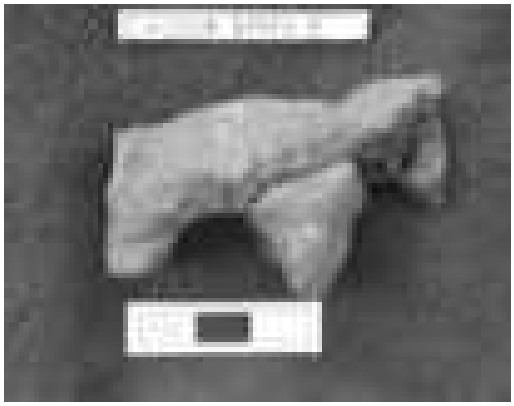


Figure 3.8
Zoomorphic figurine.
Çatalhöyük 2005 Archive Report, 179, Fig. 8.7

3.6.9. Beads and other ornaments

Personal body ornamentation at Çatalhöyük takes many forms. *In situ* ornamentation is overwhelmingly from burial contexts and may be considered expressions of identity; in dirty areas of buildings they also provide evidence of manufacture technology. Ornaments are also found in re-deposited midden and fill contexts.

Beads were the main body ornamentations in burial contexts and were made of local and exotic stones and, more rarely, of lead, copper and obsidian (Hamilton 2005b). Carnelian possibly came from the Taurus Mountains to the south and serpentine to the east of the Konya Plain (Wright 2005). Natural materials include locally sourced animal remains and dentalium from the Mediterranean (Hamilton 2005b).

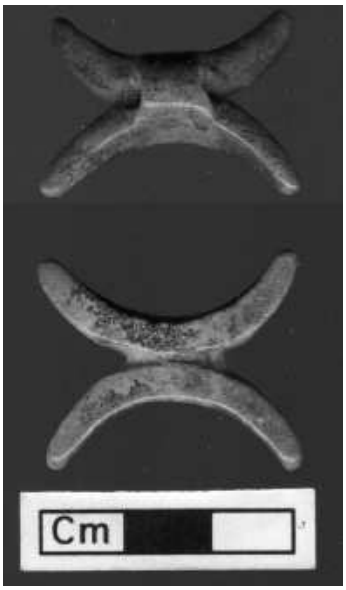


Figure 3.9
Bone buttons from a burial in Area 4040.
Çatalhöyük 2007 Archive Report, 174, Fig.125

Bone was shaped in different ways (*Figure 3.9*), varying in their degree of crafting (Russell 2005). Red deer canines, and their bone imitations, were used in necklaces and as pendants (Russell 2007a). Rough-outs of stone beads are evidence of on-site manufacture but with wide household variation in source access and usage (Wright 2006). In Building 75 (South V), a red-stone bead workshop, not found in any other building, is a rare indication of craft specialisation (Wright & Bains 2007). Bi-conical drilling was practiced from the earliest levels, arriving with the first settlers (Bains & Wright 2008).

Local stone was common throughout the occupation and became more diverse after Level IX (Bains & Wright 2008). Black serpentine was used since the Pre-XII Levels, blue-green-grey forms appeared in Levels VIII and VII, apatite-turquoise only appeared in VI–IV and carnelian in VII, V and IV (Hamilton 2005b). Dentalium was most common in Levels VI and V; deer teeth were used in Levels VIII and VII, and were imitated from Level VI onwards, especially in female and infant burials (Hamilton 2005b; Russell 2005). From Level VI, complexly carved small mammal bone necklaces were more frequent (Russell 2007a; 2008).

Rings made from caprine femurs were common from Pre-XIIA onwards midden and fill contexts (Russell 2005). One sequence of five rings cut from one sheep femur was worn by an adolescent buried in Building 1 (North, VII–VI); the wear patterns suggest lifelong use (Russell 2005). Unlike many artefacts, rings had a high degree of manufacture standardisation but were usually discarded (Russell 2005), and by later levels were no longer in evidence (Russell 2007a).

Throughout southwest Asia there was a similar pattern in bead materials, their production, and their placement in graves (Wright 2005).

3.6.10. Stamp seals

A variety of flat baked clay objects, incised with geometric patterns were possibly used as stamps for repetitive designs and are found in Çatalhöyük Levels VII–II (Türkcan 2005a). Most are geometric, but one is four-leafed, and another, from the make-up of Building 44 (South II), is in the shape of a splayed bear (Türkcan 2005b) (*Figure 3.10*).

Seals are usually recovered from midden and fill deposits, but there are examples in human burials from the Mellaart excavations (Cassidy 2008). There is notably little evidence of their use in permanent structures despite signs of heavy use. The four-leafed motif referenced those in the wall paintings in Buildings VI.B.1 and A.III.8 (Türkcan 2005a). Hodder (2006, 233) suggests that the stamp seals were mobiliary forms, used during the later occupation to take personal identity outside the home on public displays of cloth and skin decoration.

Çatalhöyük stamp seals are unique in Anatolia; but earlier examples come from Ras Shamra, 7550–6450 cal. BC, in the south Levant (Türkcan 2005a). From then on they appeared in small numbers in southwest Asian settlements but their designs were restricted to zig-zags (Türkcan 2005a). Cylindrical seals were not found at Çatalhöyük but were present in

Ghoraife and Gritille. Pebbles incised with decorations were found in nearby Boncuklu and at Khirokitia.

Figure 3.10
Splayed bear stamp seal.
Çatalhöyük 2005 Archive Report, frontispiece

3.6.11. Food waste and fuel

Middens, house fills and construction layers have animal and plant remains from food preparation and consumption, and charred wood and plant remains from fuel sources. Identification of these taxa provides evidence of the landscape resources brought into the settlement and contributes to constructing the Çatalhöyük palaeoenvironment and economy. They are discussed Chapters 4 and 5.

3.7. Human remains at Çatalhöyük

The evidence from human remains at Çatalhöyük might provide insights into any status or specialisation amongst the population, and also of the health and activities of the individuals. Again, this review limits itself to discussion of evidence that might have relevance to herders and their work.

One of the most commented upon aspects of Çatalhöyük is that their dead were buried under the platforms in clean areas of the buildings. The evidence suggests this practice was biased towards selected individuals, many of whom were female, or young and elderly males; most people, men in particular, were buried elsewhere (Molleson *et al.* 2005). These burial practices might indicate that men were considered more a part of the landscape, possibly as a function of their work. One piece of evidence to support this speculation is an older male (North, VII/VI, Building 1, Skeleton 2529) buried long after death, with signs of his corpse having been tightly wrapped and transported (Hamilton 2005c).

Grave goods provide insights into how the buried person was perceived and what status was conferred upon them (Wright & Bains 2007). At Çatalhöyük, grave goods are rare and give no clear indication of the working identity of the individual (Hamilton 2005c). Hodder (2006) suggests this indicates less concern with individual identity. However the burial in Building 42 (South V/IV) of a young woman cradling a frequently re-painted and re-plastered skull and wearing a leopard claw pendant is taken to be indicative of high social standing and a concern with constructing a history (Hodder 2006, Ch. 6). Another atypical male burial in the centre of a clean area (South VII, Building 50) includes the skeleton of a lamb (Russell & Düring 2006), and is a rare reference to domestic herding in ritual activity (*Figure 3.11*). There are parallels with antecedent practices at Shillourokambos and Khirokitia (le Mort *et al.* 2008).

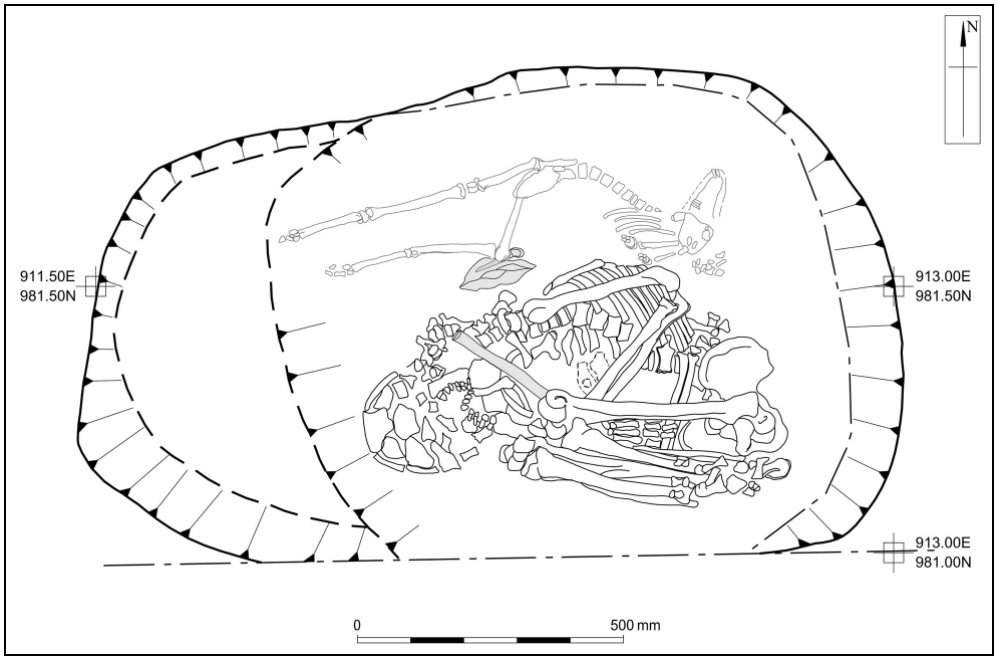


Figure 3.11
Plan of an adult male buried with a lamb in Building 50 (South Area).
Russell & Düring 2006, 77, Fig.3

The number of infant burials was not exceptionally high for pre-20th-century societies. Isotopic evidence suggests weaning was not unduly early (Richards *et al.* 2003), although dental hypoplasia identifies a period of stress soon after weaning and again between ten to thirteen years old (Molleson *et al.* 2005). Once past the dangers of infancy people could live long lives, as shown by evidence of arthritis and osteoporosis (Molleson *et al.* 2005).

Morphological evidence suggests all adults were short-statured and strongly built, although bone cortex evidence suggests males were more physically active (B. Boz & L. Hager, *pers. comm.*, 20th July 2009). Short stature might indicate a low protein diet; isotope evidence indicates that this protein was primarily from meat (Richards *et al*. 2003). Gross tooth wear suggests a diet of hard foods such as nuts and grains, crushed foods such as tubers, and uncooked pieces of vegetables; tooth wear and dental caries show that ground cereal products such as flour, meal and bran were a minimal part of the diet (Molleson *et al.* 2005). The dental caries incidence was higher at Jericho and Jarmo, but less at Çayönü, southeast and Aşıklı Höyük (Molleson *et al.* 2005). There are few work-related pathology indicators,

in comparison to evidence from Abu Hureyra, although load-carrying stresses are evident in children as well as adults (Molleson *et al.* 2005). Evidence of anaemia and lung disease is now questioned (B. Boz & L. Hager, *pers. comm.,* 20th July 2009, *contra* Molleson *et al.* 2005).

Temporal and spatial analysis is largely precluded by the skewing of the living population, frequent re-deposition, and the complexity of the site stratigraphy (Molleson *et al.* 2005) but is recently being re-attempted. One pattern may be noted; there is considerable variation in burial numbers between buildings (Andrews *et al.* 2005), and in Building 1 the number of burials exceeds that expected from house occupants alone (Düring 2005). Grave goods provide some evidence of a greater elaboration in the burials associated with buildings with the longest rebuilding sequence (Düring 2005), and Hodder (2006) argues that this evidence supports his interpretation of 'history houses' within neighbourhoods.

Genetically linked morphological and morphometric traits in teeth suggests that Çatalhöyük was a patrilocal exogamous settlement (M. Pilloud, *pers. comm.,* 29th July 2009) although the size and isolation of the settlement might suggest endogamy (Baird 2005). There might have been different moieties living in the South and the North Areas of the mound, but neither patrilinearity nor matrilinearity was evident in single houses, history houses or sequential houses (M. Pilloud, *pers. comm.,* 29th July 2009).

Under-floor burials are frequent in southwest Asian sites but painted and plastered skulls, found in the Levant, are absent in Anatolia. The long sequence at Çayönü shows change from burials in public spaces to private burials in the house, and finally to more burials outside the house (Hodder 2006, 249). At Jarmo burials were outside the settlement area. In maintaining house burials Çatalhöyük might once again have been continuing conservative practices (Hodder 2006).

3.8. Summarising the herders' cultural setting

This chapter has described the changing and unchanging material world of Çatalhöyük herders within the settlement; the findings are summed up in *Table 3.1*. There is ample evidence of a household level of production, consumption, exchange and ritual, yet there is little individual expression to be seen in the highly reiterative manner of house construction, the use of its internal spaces, the production of tools and ornaments, or the contextual associations between paintings, installations and burials. Certainly, herders would have had a clearly defined sense of place at both a household and settlement level.

There is minimal evidence for specialisation or social stratification and, if this is so, the pursuit of different activities might have been more easily managed. Multi-tasking could have integrated herding with sourcing raw materials in the wider landscape, and might have eased access to pasture land or crop by-products. However the closely-scheduled annual cycle of activities might have required reciprocal labour from other households.

Two pieces of evidence might indicate specialisation and social status. Firstly the on-site absence of most males, and the male corpses that had been moved and reburied, might indicate that men undertook off-site activities such as farming, herding and resource procurement. A gendered division of labour would have restricted labour deployment flexibility, splitting families if distant pasturing was practiced. Secondly, the possibility of 'history houses' implies a broader community organisation where domestic activities, including herding, were organised by neighbourhood rather than by household. In this situation it might have been necessary to maintain social and economic relationships in order to exchange goods. If successful, alliances might have been mutually beneficial at the expense of less successful partnerships. However building construction, tool and ornament production, and food preparation and storage, all indicate household-based activities; any community organisation would appear to have been quite limited in its remit.

Çatalhöyük maintained a conservative tradition possibly by emphasising the house. It was still able, however, to adopt new technologies, and might therefore have been amenable to new food production strategies. Parallels with the material culture of other southwest Asian settlements, coupled with extensive networks of resource procurement, confirm that Çatalhöyük inhabitants were part of a wide social sphere in which knowledge of herding practices might also have been exchanged. However parallels and differences, both in central Anatolia and in the wider region, indicate a complexity of relationships where influences on herding practices at Çatalhöyük might have had varied sources.

In earlier levels, domestic production was spatially separated from belief systems and ancestral rituals; domestic skills, including herding, appear not to have been incorporated into belief systems. Opportunities for introducing innovations or for increasing production are less where status is low. The evidence for the accumulation of small changes might indicate that the rules had begun to loosen in later levels. As the settlement became more dispersed, houses became larger and more complex, and new mobiliary forms took personal expression and identity outside the house. It is possible that the domestic sphere was gaining a more prominent place as interest in past practices and belief systems waned. The herders' skills, along with skills in other production areas, might have made an increasing contribution to social identity, and social stratification based on success in these fields might have followed.

	Material procurement and manufacture										*Scale of activity*		*Spatial patterning*		*Diachronic change (Mellart and Hodder phasing)*										
	Local fan	*Local plains*	*Sand- ridges*	*Terraces*	*Lower slopes*	*Higher slopes*	*Taurus Mts.*	*Karadağ*	*Cappadocia*	*More exotic*	*Organisational*	*Temporal*	*Within buildings*	*Across settlement*	*Pre-XIIE-A (G)*	*XII (H)*	*XI (I)*	*X (J)*	*IX (K)*	*VIII (L)*	*VII (M/N)*	*VI (N/O)*	*V (P)*	*IV (Q)*	*III (R)*	*II (S)*	*I (T)*
Settlement	n/a										?	*c.* 1200 y	n/a	Edge penning	No buildings	Rising population				Max. pop^{n}.			Declining population				
Neighbourhood	n/a										History houses?	Varied	n/a	North more spacious		Tightly packed buildings							More space				
Buildings	n/a										House	50-100 y	n/a	4040 larger		Party walls				Separate walls							
Walls	n/a										House	*c.* 10 years	n/a	None		Thinner mudbrick walls, timber uprights							Walls thicker		Brick pillars		
Bricks											House	Summer	n/a	None		Dark silty clays				Buff silty material							
Timbers											House	Re-used in new house	n/a	None		Rip-erian	Oaks and junipers										
Roofs											House	Repairs	n/a	None		No change											
Floors											House	*c.* 2 months	n/a	None		Plaster or mud								Gravel added to floor		
Plaster											House	*c.* 2 months	Clean area	None		Buff coloured				White							
Ovens											House	Varied	Dirty area	None		No change											
Bins											House	Varied	Dirty area, stores	None		No change											

Table 3.1
A summary of the spatial and temporal trends seen in the Çatalhöyük archaeological record
Note that the Phasing uses both Mellart and Hodder systems

	Material procurement and manufacture										*Scale of activity*		*Spatial patterning*		*Diachronic change (Mellart and Hodder phasing)*											
	Local fan	*Local plains*	*Sand- ridges*	*Terraces*	*Lower slopes*	*Higher slopes*	*Taurus Mts.*	*Karadağ*	*Cappadocia*	*More exotic*	*Organisational*	*Temporal*	*Within buildings*	*Across settlement*	*Pre-XIIE-A (G)*	*XII (H)*	*XI (I)*	*X (J)*	*IX (K)*	*VIII (L)*	*VII (M/N)*	*VI (N/O)*	*V (P)*	*IV (Q)*	*III (R)*	*II (S)*	*I (T)*
Hearths											House	Varied	Dirty area	None	No buildings	Round, near oven								Rectangular, nearer clean area			
Platforms											House	Varied	Clean area	None		No change											
Installations							?	?			House	Re-used in new house	Clean area	Some houses more		No change											
Paintings									?	?	House	< 3 months	Clean area	Some houses more		Plain red, geometric		Figurative, black pigment			Hunting scenes						
Burials — *Grave-goods*	n/a										House	At death or later	Clean area, midden	None													
Burials — *bodies*	n/a										House	At death or later	Clean area, midden	Area moieties		Babies in house					Babies outside house						
Burials — *Graves*	n/a										House	At death or later	Clean area, midden	House number varies		No change											
Special deposits	n/a										House	Marked events	Clean& dirty areas, middens	None		No change											
Caches	n/a										House	Varied	Dirty area, stores	None		No change											
Ornamentation — *Stone beads*											Usually house	Continue to burial	Burials, dirty area, middens	One workshop		Less diverse					More diverse materials						
Ornamentation — *Natural beads*											House	Some tooth, & pendant curation	Burials, dirty area, middens	None		Real deer teeth								Dentalium VI/V, imitation teeth, complex bone		
Ornamentation — *Rings*											House	Usually lifetime	Dirty area, middens	None		Common								Rare		
Stamp seals											House	Continue to burial	Burials, middens	None		Absent									Present		

Table 3.1 cont.

	Material procurement and manufacture										*Scale of activity*		*Spatial patterning*		*Diachronic change (Mellart and Hodder phasing)*										
	Local fan	*Local plains*	*Sand-ridges*	*Terraces*	*Lower slopes*	*Higher slopes*	*Taurus Mts.*	*Karadağ*	*Cappadocia*	*More exotic*	*Organisational*	*Temporal*	*Within buildings*	*Across settlement*	*Pre-XIIE-A (G)*	*XII (H)*	*XI (I)*	*X (J)*	*IX (K)*	*VIII (L)*	*VII (M/N)*	*VIN (O)*	*V (P)*	*IV (Q)*	*III (R)*	*II (S)*	*I (T)*
Anthropomorphic Figurines		■		■							House	Ephemeral mostly	Rare abandonment deposits	None	No change												
Zoomorphic	■										House	Ephemeral	Not in houses	None	No change												
Abbreviated		■									House	Ephemeral	Not in houses	None	No change												
Obsidian Chipped stone										■	House	Cache of imported	Dirty area, stores, middens, fills	None	Micros, local	Bipolar blades. Local & Kaltepe cores					Unipolar blades new source					
Flints									■		House	Not curated	Dirty area, stores, middens, fills	None													
Bone tools	■										House	Varied	Dirty area, stores, middens, fills	None	Less woodworking				More woodwork, soft hammers		More groove splitting, pressure flakers, burnishers					
Ground-stone							■	■			House	Curated	Middens, fills, dirty area cache.	None	No change												
Clay balls	■				?						House	< few months	Dirty area, caches, ovens, midden, fill	None	Local, shapes	Mineral rich sediment					Rapid disappearance					
Pottery	■				?						House	No curation	Midden, fills	None	Acer-amic	Mainly local clay, organic tempered					Mineral rich, more burnishing, form, decoration					
Baskets/ mats	■	■									House	Seasonal collection	Dirty & clean areas, burials, stores	None	Reeds, rushes, grasses										Barley straw introduced	

Table 3.1 cont.

CHAPTER 4. THE ÇATALHÖYÜK ZOOARCHAEOLOGICAL EVIDENCE

4.1. Introduction

The aim of the previous chapter was to describe the settled context in which Çatalhöyük herders might have lived, in order to situate herding within social and ritual life. This chapter focuses on sheep herding itself, through review of the zooarchaeological evidence at Çatalhöyük. The review contextualises domestic sheep herding within the wider economy through discussion of the evidence for the exploitation of other animals. Edible plants also contribute significantly to the food economy, but are discussed as part of the Çatalhöyük palaeoenvironment in *Chapter 5*.

The Çatalhöyük animal remains from the 1960s excavations (Mellart 1967) were reported by Perkins (1969) and a portion of the assemblage was analysed by Ducos (1988) but, as will be discussed, their findings were questioned by Russell and Martin (2005) who were the authors of the animal remains report for Hodder's 1995–1999 excavation seasons. The differences of interpretation were due, in part, to the later introduction of more robust retrieval methods that included sieving and flotation, producing a larger and more representative zooarchaeological assemblage. In addition, analysis and interpretation was facilitated by the adoption of a more comprehensive identification system, and extensive recording based on Meadow's (1978) 'Bonecode' (Russell & Martin 2005, 35–36). However, as on-site archaeological assemblages probably derived primarily from animals selected for slaughter, it should be remembered that the composition of herd parts containing breeding animals, or those being fallowed, might not be represented.

<table>
<tr><th>Mellart Phases</th><th>Hodder Phases</th><th>Russell & Martin (2005)</th><th>Twiss et al. (2010)</th><th>Groups in this research</th></tr>
<tr><td></td><td>4040 G</td><td rowspan="6">ne</td><td>4040 G</td><td rowspan="2">4
4040 & IST</td></tr>
<tr><td></td><td>4040 F</td><td>4040 F</td></tr>
<tr><td>I</td><td>South T</td><td rowspan="4">3rd period</td><td>6
(with TP)</td></tr>
<tr><td>II</td><td>South S</td><td rowspan="2">5</td></tr>
<tr><td>III</td><td>South R</td></tr>
<tr><td>IV</td><td>South Q</td><td rowspan="2">3
North, South, Bach & Summit</td><td>3</td></tr>
<tr><td>V</td><td>South P</td><td rowspan="2">ne</td><td rowspan="2">ne</td></tr>
<tr><td>VI</td><td>South O
South N</td></tr>
<tr><td>VII</td><td>South M</td><td rowspan="6">2</td><td rowspan="6">2nd period</td><td>2</td></tr>
<tr><td>VIII</td><td>South L</td><td rowspan="2">1b</td></tr>
<tr><td>IX</td><td>South K</td></tr>
<tr><td>X</td><td>South J</td><td rowspan="3">ne</td></tr>
<tr><td>XI</td><td>South I</td></tr>
<tr><td>XII</td><td>South H</td></tr>
<tr><td>Pre-XIIa
Pre-XIIb
Pre-XIIc
Pre-XIId
Pre-XIIe</td><td>South G</td><td>1
(with KOPAL)</td><td>1st period</td><td>1a</td></tr>
</table>

Table 4.1
Summary of Mellart and Hodder Phases, and the zooarchaeological analytical groupings used by Russell & Martin (2005), Twiss et al. *(2010), and in the research presented in this thesis*

The backbone to this chapter is taken from Russell and Martin's (2005) detailed report, subsequent yearly archive reports summarising findings from the Hodder 2000–2009 seasons, and a discussion paper in preliminary draft (Twiss *et al.* 2010). The contributions made by these publications to an understanding of the palaeoenvironment and site formation processes are discussed in *Chapters 5* and *9* respectively.

In chronological analyses, Russell and Martin (2005, 38) consider the evidence from 342 targeted units (NISP = 24,149) in three phases (*Table 4.1*). The earliest Phase 1 includes evidence from South Area Pre-XII Levels and the KOPAL Area; Phase 2 contains South Area Levels XII–VII material, and Phase 3 takes data from the North, Bach and Summit Areas which are typologically assigned to Levels VI–IV; there is no evidence from Levels I–III or the 4040 Area. Twiss *et al.* (2010) begin to examine a much larger assemblage (NISP

= 70,917), expanding the evidence and interpretation of later occupation phases. They use new Hodder Phasing, where Mellaart Levels Pre-XII to I are re-labelled South G to South T (Farid 2008) and the 4040 Area divided into 4040G and 4040F; where appropriate, they discuss the evidence into three analytical periods. The authors of both publications do not include evidence from the TP or IST Areas.

4.2. Reliance on different species

In discussing the relative proportions of taxa, Russell & Martin (2005, 39–46) address certain taphonomic and recording problems; biases in species and element representation might be introduced by retrieval methods and post-depositional attrition; insecure chronological and spatial resolution might result from re-deposition; species richness might primarily reflect sample size; and relative proportions of taxa might be distorted by shortcomings in the NISP quantification method. They summarise the proportions of major ungulate taxa using data restricted to primary and secondary depositional contexts, to unit assemblages >50, and by using Watson's (1979) diagnostic-zone method for across-taxa standardisation (*Figure 4.1*). Twiss *et al.* (2010, 5) record data from all recorded unit assemblages, and use diagnostic zones to establish species representation (*Figure 4.2*).

Similar patterns emerge in both datasets; Russell and Martin (2005) show that caprines dominate every on-site occupation phase, rising to 94.3% towards the end of the Neolithic settlement, and cattle only dominate (>50%) in the settlement-edge KOPAL assemblage. In the on-site units, caprines are followed by cattle in order of representation, then equids, wild boar and finally deer. Twiss *et al.* (2010) describe three broad periods that also emerge in Russell and Martin's (2005) data. The earliest period (South G) is very similar to the latest period (South P–T) in its proportional representation of taxa, whereas the middle period (South H–M) is notable for caprine representation falling to its lowest at 58.9%. In the

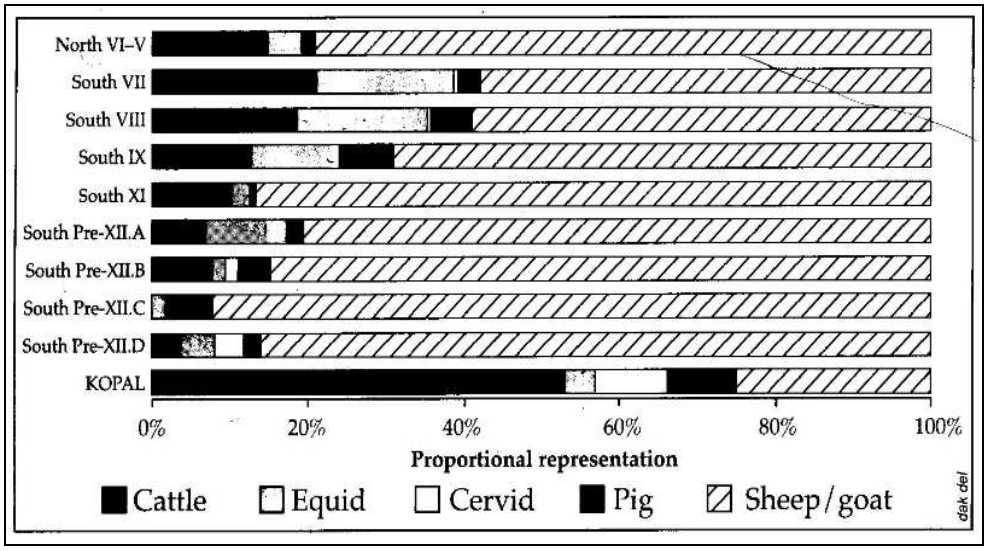


Figure 4.1
Proportions of major ungulate taxa by excavation areas and levels. Specimens from primary and secondary deposits only, quantified by diagnostic zones; contexts with <50 diagnostic zones excluded. Russell & Martin 2005, 46, Fig. 2.4

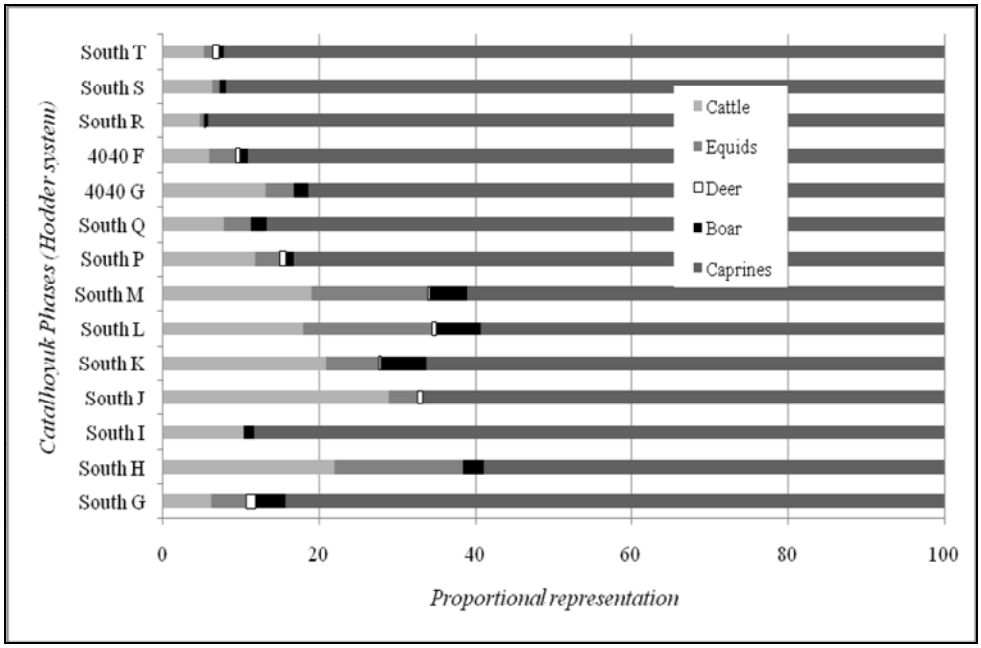


Figure 4.2
Chart showing NISP % of major ungulate taxa (using diagnostic zones). After Twiss et al. *2010, 5*

middle period, cattle average 19.8% and equids rise to *c.* 16%, but in the last period, cattle fall to an average of 7.8%, and equids to 3%.

The anthropogenic midden contexts of Çatalhöyük are dominated by caprine remains. Less than 12% of the caprine NISP can be separated by morphological and morphometric criteria into sheep or goat, of these, sheep far outnumber goat in an average 7:1 ratio throughout the occupation of the settlement (Russell & Martin 2005, 67). These findings from the 1990s excavations overturn the first zooarchaeological analyses of the animal remains from the 1960s' excavations at Çatalhöyük where cattle were found to dominate the hand-retrieved assemblage (Ducos 1988; Perkins 1969), and provide convincing evidence of overwhelming reliance on caprines, and sheep in particular.

The zooarchaeological assemblage includes a range of other wild species that might have contributed to the Çatalhöyük food economy; this contribution was small and for many species would probably have been seasonal. Of the mammals, only foxes, domestic dogs, hares and badgers have butchery marks consistent with consumption, and it is suggested that either the pelts, or the skulls and claws, were the main exploitation focus of other species (Russell & Martin 2005, 80–84). Bird remains are heavily biased towards large wetland species, but taphonomic factors might have contributed to this pattern. The predominance of wing elements is indicative of their main exploitation having been for their feathers, with meat only having been of secondary importance (Russell & McGowan 2003, 2005, 109). The large eggshell assemblage might suggest their importance in the diet, to the extent that some management is proposed; however, egg yolk for pigment binding might have been the main goal (Sidell & Scudder 2005, 121). There is no indication of consumption of any microfauna (Jenkins 2005) or molluscs (Reese 2005).

4.3. Exploitation of ungulate taxa

4.3.1. Sheep (*Ovis aries, O. orientalis*)

Russell and Martin's (2005, 68) metrical analysis of sheep elements by log-size indices, supports Ducos' (1988) interpretation that the sheep were domestic (*contra* Perkins 1969).

The size of most identifiable sheep elements falls between later known domesticates and both nearby modern wild sheep and Aşıklı archaeological sheep (Russell & Martin 2005, 69) and, as the sizes remained unchanged throughout the Neolithic occupation, it is suggested that the first Çatalhöyük settlers brought domestic herds with them. There are a few large elements, attributed to wild species, extant in the Çatalhöyük landscape.

If almost all elements can be considered to derive from domestic sheep, it is possible to attribute any size dimorphism to differences in size between males and females. Russell and Martin's (2005, 71) interpretation indicates slightly more males in Phase 1, but slightly more females in Phases 2 and 3. However, in the sheep pelves assemblage, males (42) and females (44) are evenly divided by morphological criteria (Russell & Martin 2005, 70), and, when divided into chronological periods, no apparent patterning emerges (Twiss *et al.* 2010, 6) Arbuckle *et al.* (2009, 140) use dimorphism in fused and unfused metacarpals to identify the proportions of males and females among unfused young (<24 months) and fused older (>24 months) individuals. They found that, in the assemblage encompassing Pre-XII–IV Levels, large (male) and small (female) specimens were present in equal number in both young and old sheep (*Figure 4.3*). All three analyses suggest that little distinction was made between slaughtering of male and female sheep at Çatalhöyük.

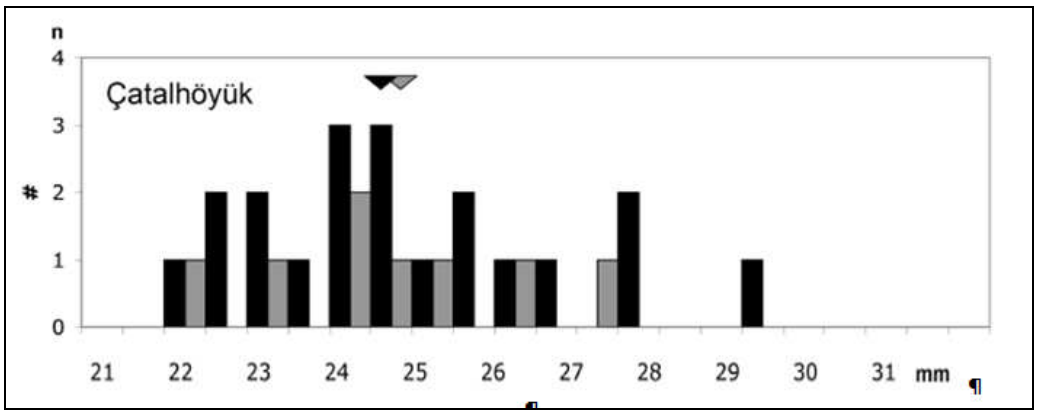


Figure 4.3
Chart showing distributions of measurements of the distal breadth of sheep metacarpals for fused(black) and unfused (grey) Çatalhöyük specimens (n = 24). Mean values displayed as triangles.
Arbuckle et al. *2009, 140*, Fig 6

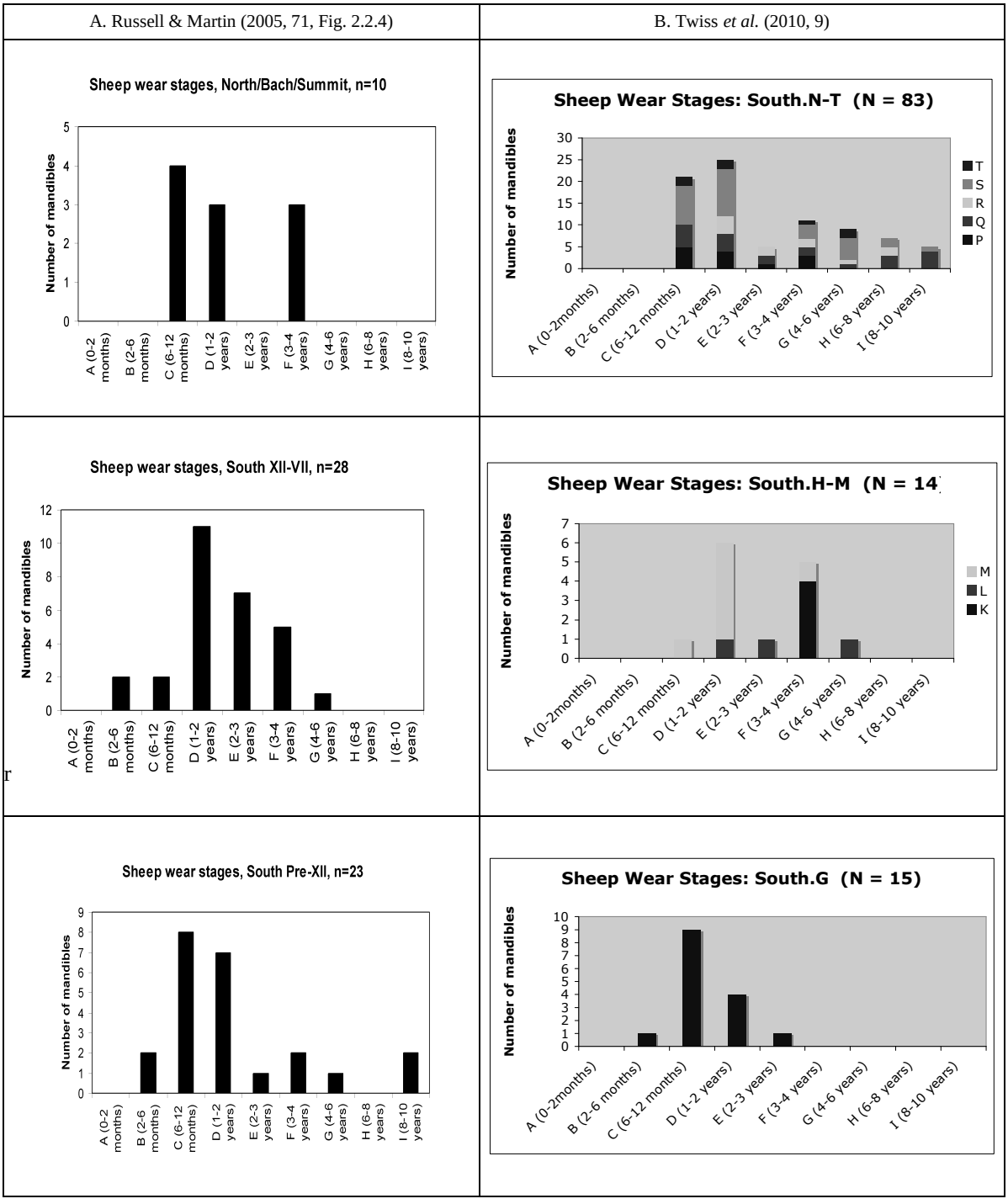


Figure 4.4
Charts showing tooth wear stages in Çatalhöyük sheep specimens, by analytical groupings. A. Russell and Martin 2005, 71, Fig. 2.2.4*; B. Twiss* et al. *2010, 9*

Examination of dental eruption and bone fusion evidence can give suggested ages of death of each animal, and an interpretation of herd product goals might be made from the assemblage patterning (*Figure 4.4*). Russell and Martin's (2005, 71) dental aging evidence shows that most caprines were slaughtered as juveniles between one and two years old. Some animals were kept alive until they were older in the earlier Pre-XII Levels, and after that time some sheep were culled as sub-adults and early adults between two to four years old. The authors point out that there are many examples of neonate caprine remains at Çatalhöyük, and that their absence in the tooth data probably has a taphonomic cause. The additional material retrieved from later levels, up to South T, adds confirmation to a slaughtering peak between one and two years old (Twiss *et al.* 2010, 9). The large sample size (83) provides convincing evidence that some sheep were being kept alive much longer, at least in the South Area.

Russell and Martin's (2005, 73) assessment of age of death using bone fusion data finds the one- to two-year-old peak to be less dramatic and, instead, the slaughter pattern extends over a few years, from six months to over two and a half years; these data are not yet available for Levels 1–3.

A balanced body part representation suggests caprines were not transported any distance between the slaughter site and the settlement, and an under-representation of ribs and vertebrae suggests that butchery might have taken place before carcass parts were brought onto site for consumption. Once on site, butchery marks and fragmentation patterns on caprine bone attest to their heavy exploitation for their meat and fat, and also for tool and ornamentation manufacture. The high degree of bone fragmentation, seen in all food species but particularly in caprines, and in all occupation levels, but most strongly in the Pre-XII Levels, suggests that the fat from the bone and marrow was as important as meat (Russell &

Martin 2005, 94). An analysis of the contexts of deposition, by species representation, body part representation and degree of bone fragmentation, suggests that meat and fat products from sheep and goat contributed to 84% of daily meals, 58% of feasts and 53% of other special meals (Russell & Martin 2005).

It is agreed that the focus on slaughtering juvenile sheep, throughout the settlement's occupation, fits well with models for meat, or meat and non-intensive milk production (Arbuckle *et al.* 2009; Russell & Martin 2005; Twiss *et al.* 2010). In Pre-XII Levels, the evidence of some sheep living longer might suggest they were kept alive as food goals focused more on fat than meat, or because whole herds were kept closer to the settlement making all deaths more visible (Russell & Martin 2005, 74). Arbuckle *et al.* (2009, 139) find it interesting that many sheep were not culled until three or four years old and suggest that product demands were easily met, and that winter graze or fodder was sufficient to overwinter sheep beyond their maximum productive age. In addition, they point out that the near equal slaughter of males and females, at least up to Level IV, is not a typical meat optimisation pattern, and suggest that different practices were in place.

Reliance on sheep for their meat and fat products is in marked contrast to their representation in various ritual settings, unlike many wild species (*Table 4.2*) (Hodder 2006, 9). There are no sheep depicted in paintings, the few reliefs and installations in Levels X–VI might be small cattle, and the zoomorphic quadruped figurines are difficult to assign to species. Rare special deposits include a sheep frontal cradling a clay ball in Level VII/VI and the burial of a lamb with a male in South Level VII (Russell & Düring 2006; Russell & Meece 2005).

%	*Paintings*	*Reliefs*	*Installations/deposits*	*Faunal remains*
Hedgehog	0	0	0	<1
Hare	0	0	0	1
Wolf	0	0	1	<1
Dog	1	0	2	5
Fox	0	0	1	2
Bear	1	0	1	<1
Mustelid	0	0	1	<1
Wild cat	0	0	0	<1
Leopard	65	35	0	0
Equid	6	0	1	8
Boar	3	0	13	3
Fallow deer	1	0	1	<1
Red deer	12	0	1	1
Roe deer	0	0	0	<1
Cattle	1	46	54	15
Goat	10	0	11	9
Sheep	0	19	13	56

Table 4.2
Percentage of mammalian taxa found across different media at Çatalhöyük. Hodder 2006, 9, Table 1

The contextual evidence suggests that sheep products fell within the domestic sphere of Çatalhöyük life (Hodder 2006, 53). The evidence for storage arrangements in burnt buildings points to a household level of plant consumption (Bogaard *et al.* 2009) but does not comment on everyday meat consumption. It is possible that the highly homogeneous assemblage of fragmented caprine remains seen in the Level Pre-XII settlement-edge contexts indicates a period of whole settlement activity, later replaced by household-based consumption where waste was deposited in middens (Russell & Martin 2005, 80).

4.3.2. Goats *(Capra hircus, C. aegagrus*)

A small sample (25), assessed by log-size indices, tentatively suggests that there were domesticated goats at Çatalhöyük; however, there are 21 specimens in special deposits with wild horncore morphology (Russell & Martin 2005, 69); a reminder that wild goats also played a role in the ritual sphere. Arbuckle *et al.* (2009, 138) support this interpretation of domestication using astragali sizes (NISP = 10). The small goat NISP precludes safe zooarchaeological analyses of age or sex, so slaughtering patterns and product goals cannot

be interpreted (Russell & Martin 2005, 71; Twiss *et al.* 2010) although, as the combined caprine slaughter curves are older than they are for sheep alone, Arbuckle *et al.* (2009, 139) argue that this is evidence of goats being slaughtered slightly older than sheep at Çatalhöyük up to Level IV. More generally, the butchery and deposition patterns for goats closely follow those of sheep, and it is likely that their products were also consumed within the domestic sphere.

4.3.3. Cattle (*Bos primigenius*)

The exploitation of cattle at Çatalhöyük has been of great interest, partly stemming from Perkins' (1969) assessment that they were the greater contributor to the settlement economy, but also because their presence in installations, paintings and special deposits is such a feature of Çatalhöyük's material culture (*Chapter 3*). Any changes in cattle exploitation might be expected to have an impact on sheep herding.

Ducos' (1988) suggestion that there was some form of early cattle management found limited support in body part representation that indicated whole animals were brought to the site (Russell & Martin 2005, 47). Nevertheless, careful examination of morphometric evidence led Russell and Martin (2005, 48–51) to conclude that the remains conformed to a bimodal distribution of males and females in the wild size range, although there were increasing numbers of females after Level VII. Cattle age and sex data were limited, and in addition, contextual analysis of the remains highlighted differences in practices associated with feasting and everyday consumption. Russell and Martin's (2005, 54) interpretation is that cull patterns did not conform to those expected for herded animals, even with a slight increase in sub-adults at the expense of adults over time (from Level Pre-XII: 22%, Levels XII–VII: 36%, Levels VI–IV: 43%).

However the latest work, that includes more specimens from later levels of occupation, shows an increased reliance on cattle from South G (6.2%) to South H (21.9%), which

sharply decreased again between South M (19%) and South Q (7.7%) (Twiss *et al.* 2010) (*Figure 4.2*). Morphometric analysis confirms previous interpretation up to South M, but in South N–T there is a significant shift towards smaller animals and possibly also a reduction in sexual dimorphism (Twiss *et al.* 2010, 13) (*Figure 4.5*). Preliminary age analysis, using combined tooth and bone fusion data, finds that infantile and juvenile cattle percentages are greatest in South N – T, but not earlier in 4040 or IST assemblages (Twiss *et al.* 2010, 11).

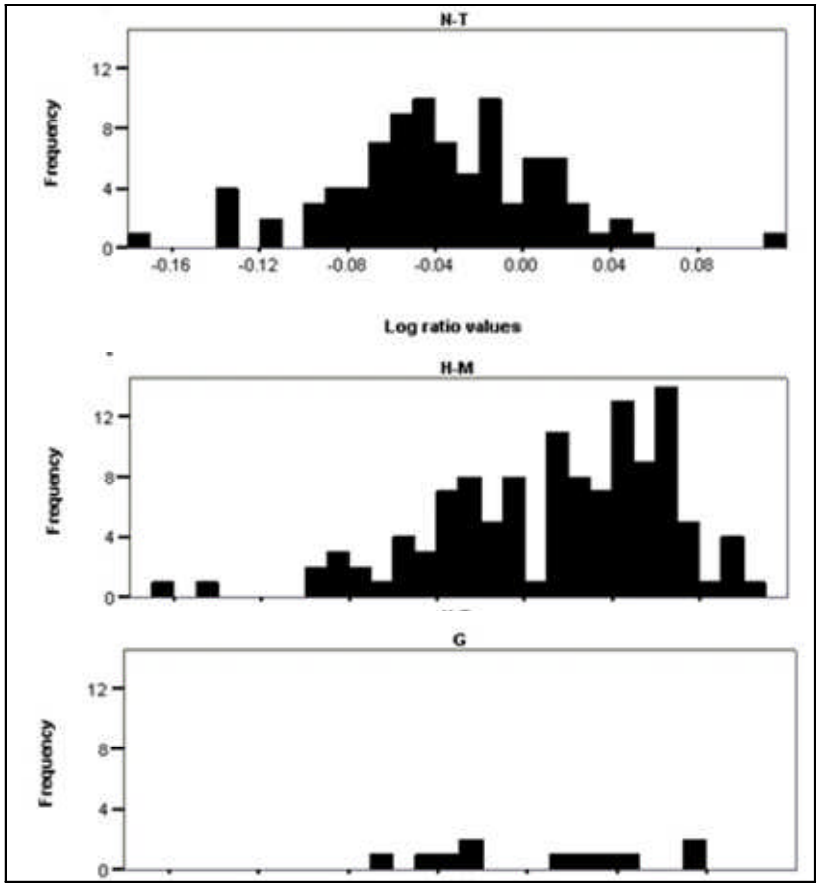


Figure 4.5
Cattle standard animal graphs for South Area by analytical grouping of Hodder Phases. Twiss et al. *2010, 14*

The use of wild cattle bucrania and horns in installations and special deposits, the representation of cattle in figurines and painting (*Table 4.2*), and their contextual appearance in the 'clean' house areas places wild cattle in Hodder's (2006, 53) sphere of exchange and ancestry. In the KOPAL Area, differences in reliance on male cattle, as well as in their body

part representation and butchery patterns, may be compared to on-site evidence of every-day cattle consumption; this is interpreted as the KOPAL Area having been a settlement feasting area (Russell & Martin 2005, 52). Without further settlement-edge excavation it is unclear whether settlement feasting activities continued later into the occupation, although wild cattle continued to be part of the zooarchaeological assemblage alongside the smaller, probably domestic forms (Twiss *et al.* 2010, 13).

Twiss *et al.* (2010, 17) speculate that the size of the domestic cattle herds might have been small because herding was only adopted when wild herds became over-hunted or when labour had become more focused on herding, and that domesticates might not have carried the symbolic value of wild hunted aurochs. It is intriguing that a renewed reliance on caprines coincided with the emergence of small domestic cattle herds. In summary, whilst hunted wild cattle remained central to identity at Çatalhöyük, possibly used to maintain conservative traditions, the evidence suggests that cattle herding, on a small scale, also became part of the domestic economy.

4.3.4. Equids

Russell and Martin (2005, 57–60) identify three species of wild equids, by tooth morphology, in the Çatalhöyük assemblage: *Equus ferus, E. hemionus* and *E. hydruntinus.* Age data points to 70–90% adults in the assemblage, and body-part representation suggests that whole animals were brought to the settlement; these analyses are in keeping with targeted, rather than mass-kill hunting strategies. Throughout the occupation, equid remains represented <3% of the ungulate assemblage, except in South H, L and M where they reached *c.* 17%, in similar proportions to cattle (Twiss *et al.* 2010) (*Figure 4.2*).

Unlike cattle, there is no evidence to suggest equids were treated differently in the KOPAL Area and, in addition, their ritual representation is limited to wall paintings (Russell &

Martin 2005, 58) (*Table 4.2*). The depositional contexts indicate that equid products were used in everyday consumption and rarely in household feasting.

4.3.5. Deer

Three cervid species, red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*), are identified in the Çatalhöyük assemblage, red deer being the most common (Russell & Martin 2005, 60). In Twiss *et al.*'s (2010) analysis of proportional representation by diagnostic zone (*Figure 4.2*), deer remains are rare: < 1.2% of the ungulate assemblage; however, the figure rises to 7% in the KOPAL Area (Russell & Martin 2005, 60) (*Figure 4.1*). An interpretation of body parts suggests that only antlers and skins were taken into the settlement, whilst meat-bearing bone remained at the settlement edge except in Levels Pre-XII A and B (Russell & Martin 2005, 60).

The early abandonment of any on-site exploitation for venison might have been due to habitat loss near the settlement, however, in later levels of occupation, the continuing evidence for deer bone in special deposits, and for depictions of deer hunting in wall paintings, stands testimony to their continuing ritual or social importance (Russell & Meece 2005) (*Table 4.2*). Unlike cattle, it appears that deer skin and antlers were the prized products, whereas venison was rarely consumed

4.3.6. Wild boar (*Sus scrofa*)

Boar numbers are consistently low throughout the settlement sequence, averaging 5.1% in South G, K, L and M, but otherwise averaging 1.3% (*Figure 4.2*); they are more common in the KOPAL Area (6% by diagnostic zone) (Russell & Martin 2005, 63). Metrical analysis places all specimens in the wild boar size range, and limited sex data is not consistent with herd management. Not unexpectedly, given the size of pig litters, there are high numbers of infants and juveniles (Russell & Martin 2005, 53). Like deer, body-part representation provides evidence of meat-bearing bone in the earliest levels and in the KOPAL Area, but

on-site evidence is restricted to skull parts and foot-bones associated with the use of their skulls and hides.

There are figurines that might represent wild boars, but no depictions in paintings; an adult wild boar scapula has been found as a special deposit, and there are 19 examples of wild boar head installations from Levels VII and VI; one modified skull might have been a headdress (Twiss 2006) (*Table 4.2*). If palaeoenvironmental reconstruction of nearby wetland and marshland habitats suitable for wild boars is correct (*Chapter 5*), it is of interest that wild boars were part of the ritual life of Çatalhöyük but not of everyday domestic life.

4.4. Other evidence of herding practices

Before summarising the zooarchaeological evidence of animal exploitation at Çatalhöyük, other contributions to the understanding of herding practices are discussed.

4.4.1. Animal pens

Most sheep remains were found in midden deposits, however in Levels Pre-XII, XI and IX deciduous dentition and perinatal caprine bones, some in articulation, were found in a few penning deposits on the settlement edge (Russell& Martin 2005, 76). In addition, microstratigraphy identified penning deposits of dung from large and medium sized ungulates; these were in heavily compacted layers that might have resulted from animal trampling (Matthews 2005, 385–391). There was also a high presence of spherulites associated primarily with sheep faeces (Canti 1999). These studies provide evidence that some caprines gave birth on site; however, it is unlikely that there was enough space, or fodder resources for the whole herd to be penned.

4.4.2. Pathology, disease and health

The pathology rate (<0.3%) in caprines is low (38 occurrences), with only three that might possibly indicate penning elbow associated with close confinement, some with foot problems that might be associated with penning or grazing in wet conditions, and two horn core deformities that might have arisen from stress (Russell & Martin 2005, 75). Whilst these pieces of evidence add some support to the use of penning, the general picture is of a healthy population.

A pilot study examining the histology and ultrastructural chemistry of sheep tibia, throughout the Çatalhöyük sequence, also found that male and female sheep and goats were in good condition, were not susceptible to long-term effects from injuries, and were able to maintain condition during their lives (Pawlowska 2007). In summary, it appears that it was possible for Çatalhöyük herders to husband their sheep well.

4.4.3. Feeding practices

Dung in penning deposits and interpreted charred dung remains in fire rake-outs might give evidence of herding and foddering practices, however there are a number of caveats, as outlined in *Chapter 1.5.2.2*; only the contents of identified pellets provide secure evidence of ingested foods, and even so the evidence might have suffered taphonomic loss of information (Mainland 1998a). In addition, this indirect evidence cannot determine whether the animals were grazing or being foddered (Mainland 1998a) nor whether dung derived from sheep or goats – animals with different feeding ethologies. Examination of caprine dung pellets at Çatalhöyük is restricted to a few that contained parenchymous tuber material and grass phytoliths (Mathews *et al.* 1997, 302), and some that contained seeds from wetland *Bolboschoenus maritimus* and *Aeluropus* (Ryan 2010).

Carbon stable isotope signatures in bone give evidence of diet averaged over the months or years of bone remodelling. Evidence from Çatalhöyük suggests that sheep, but not goats, experienced a broadening in their diet between Level XIIB and XIIC, unrelated to any climate changes (Pearson *et al.* 2007; Richards *et al.* 2003). The authors associated the isotope signature in sheep with an increased diet of plants with C4 pathways, and suggested that the sheep were being introduced to a wider range of pasture resources, possibly as the settlement needed larger flocks. Temporal analysis of a South Area building sequence (B65 – 56 – 44) shows a continuing trend towards greater dietary variation in later Levels (South Q–T) (Pearson 2010, 30). It cannot be determined whether this food was eaten as graze on seasonal growth in the wider Çatalhöyük environment, or out of season fodder brought to more confined settings nearer the settlement, nevertheless food resource exploitation appears to have changed after the initial period of occupation. The evidence suggests that resource provision for goats was somewhat different, adding support to Arbuckle *et al.*'s (2009) suggestion that small goat herds might have been raised separately.

4.4.4. Herd movement

Dung and stable isotopes can provide evidence of food ingestion, but not of where or when that happened. Nevertheless, Pearson *et al.* (2007) argue that it might be inferred from the isotopic evidence of widening resource exploitation after Level XIIB, that herding had moved further from the settlement and that the role of herding had become more separate. If pastures were tied to households, the dietary signatures in the later household sequence (B65 – 56 – 44) might be expected to have remained the same, and so Pearson (2010, 31) argues that herds were moved around a range of pastures, or were brought to the household from a number of satellite locations.

At present, the only other evidence of herd movement is a small longitudinal study of the distal metapodial morphology of sheep and goats (Sheldon 2009). The study found that there were no changes over time and it is interpreted that herding on steep hillslopes at greater

distances from the settlement was not introduced during the Çatalhöyük Neolithic settlement.

4.4.5. Product intensification

The Çatalhöyük zooarchaeological evidence convincingly points to herding for meat and fat products, however, it is possible that milk was being utilised on a small, but invisible scale. Organic residue analysis of the lipids absorbed into pottery vessels during cooking can identify the chemicals and isotopes that distinguish between ruminant adipose fats and dairy fats (Copley *et al.* 2005). In the five potsherds that yielded enough lipids for analysis, the signatures were all consistent with animal adipose fat derived from ruminants; there was no evidence of milk lipids in any vessels, nor on nine clay balls that were also analysed (Copley *et al.* 2005). The longitudinal study by Evershed *et al.* (2008) added support; the authors found very low milk lipid presence that might indicate that milk was used in the Neolithic of central Anatolia, but that product intensification was not yet in place.

4.5. Summary

The work of herding might be considered in two ways. Firstly, contextualised within the settlement, domestic animal products fall within Hodder's (2006, 53) sphere of domestic production, as they were absent from the 'clean area' of houses (Bogaard *et al.* 2009; Twiss *et al.* 2008), and their waste was typically discarded outside the house. In addition, there is a marked lack of representation of domestic animals in the art forms. Secondly, contextualised within the settlement economy, domestic herding falls within the sphere of community (Hodder 2006, 53), where organising rules might have been needed for the patterned use of the landscape and the integrated exploitation of wild and domestic plants and animals.

Çatalhöyük settlers continued to hunt wild ungulates throughout the occupation of the settlement, including wild forms of species that were also domesticated or managed. Equids

were used, in small numbers, for both domestic and feasting consumption, whereas deer and pig contributed almost nothing to the food economy after the earliest levels and might have been taboo. Cattle exploitation patterns changed during the occupation of Çatalhöyük, first with an increasing reliance on morphometrically wild cattle, possibly in early stages of management, and then, as reliance on cattle decreased again, with the appearance in the South Area of smaller cattle exhibiting less sexual dimorphism and possibly representing fully domestic species. Meat from cattle was an important contributor to both domestic and ritual consumption.

However, the settlement was heavily reliant on domestic caprines, and sheep in particular, from the outset. The sheep were herded primarily for their meat, with no evidence of product intensification over time, although fat might have been more important in the earliest years of occupation. In addition, it seems that sheep were generally healthy and that there was no pressure, either from society or from food resources, for prompt slaughter on reaching optimum maximum meat weight. However, sheep food-provisioning widened over time, raising interesting questions about changing herd mobility or exchange with other herding communities. Goats were probably also domesticated. They were slaughtered slightly older than sheep and show no evidence of widening diet over time, raising the possibility that small goat herds were managed differently from sheep, for different product goals.

4.6. Regional comparison

The evidence for early antecedents to Çatalhöyük's ungulate exploitation in its immediate locality is limited toPınarbaşı A, where interpretation suggests that caprines contributed 23% to the meat diet of sedentising hunter–herders (Baird 2006, 2007; Carruthers 2003; Martin *et al.* 2002). Recent excavations at Boncuklu reveal the first evidence of domestic grain on the Konya Plain whilst animal exploitation remained broad spectrum hunting (Baird 2008). In Aşıklı Höyük there is evidence of reliance (70%) on managed sheep (Buitenhuis 1997). The

emerging importance of feasting on wild cattle in the late Aşıklı settlement is echoed in the imagery and statuary of Çatalhöyük, and might suggest that Aşıklı contributed traditions of ritual and economy to the founding of Çatalhöyük.

In other parts of southwest Asia, evidence indicates widespread attempts to manage pigs, sheep, goats and cattle, which included handling and moving animals to areas outside their native habitats (Ducos 1993; Saña i Seguí 2000; Vigne & Buitenhuis 1999; Wasse 2007; Zeder 2006). In southeast Anatolia, at Nevalı Çori, there is evidence showing that fully domesticated, morphologically small caprines were already increasingly important to the food economy, alongside domestic pigs and managed goats (Peters *et al.* 2005). At Çayönü, sheep, cattle and pig management is interpreted (Hongo *et al.* 2009) and at Cafer, pigs are considered to have been fully domesticated (Çambel & Braidwood 1980). A possible deep-time trajectory influencing Çatalhöyük herders, models people experimenting in different ways with received ideas of herd management focused on meat production and on arable cultivation, but with a reliance on hunting and gathering wild foods. It is to be noted that the first Çatalhöyük settlers appear not to have taken up pig or cattle husbandry.

The dissemination of peoples and ideas in the following years was the forerunner to a period where the material culture and economic practices had, at one level, a greater cohesion and hegemony throughout much of southwest Asia. It is in this context that Çatalhöyük was first settled with domestic sheep and crops (Russell & Martin 2005). At this time, Süberde had sheep that were larger than those at Çatalhöyük though not as large as at Aşıklı; culling between one and three years old is indicated for both sexes and suggests they were domesticated (Arbuckle 2008a).

In the wider southwest Asia region, the evidence is of widespread management and domestication of all four herd animals, at its most advanced in the northern Fertile Crescent (Peters *et al.* 2005). The evidence suggests that at first hunted food remained the prime

contributor to the economy, relegating domestic herds to a fall-back, 'walking larder' provision at Abu Hureyra (Legge & Rowley-Conwy 2000) and Gritille (Stein 1989), and an unreliable provision whilst herd security was first being established at Halula (Saňa Seguí 2000). There is recent evidence of milk products becoming a subsistent food (Vigne & Helmer 2007) and for more focused skin and fibre exploitation (J-D.Vigne pers. comm., March 2009, Wenner-Gren Symposium). Domestic sheep introductions had, by now, largely replaced goats at 'Ain Ghazal (von den Driesch & Wodtke 1997) and Ali Kosh (Hole *et al.* 1969; Zeder 2006). In Gürcütepe, cattle and pigs are considered to have been domestic (Hauptmann 1999), and cattle were under early management at Halula (Saňa Seguí 2000).

As the first settlement of Çatalhöyük followed the widespread increasing reliance on domestic sheep, it explains, in part, their importance to the Çatalhöyük economy. However, in the earlier occupation levels, received knowledge of cattle and pig domestication does not appear to have been swiftly adopted by Çatalhöyük herders, despite the rapid uptake of chipped stone and ceramic technologies during this period.

At the end of the Levantine LPPNB/C there is evidence of settlement collapse in the Levant and southeast Anatolia, and new settlements were established. Bouqras and Tel es Sinn were established outside areas of rain-fed agriculture, with domestic sheep herding but little arable farming (Clason 1979/80); coastal settlements, such as Atlit Yam (Galili *et al.* 1993), focused on fishing rather than herding; oasis settlements, such as Azraq 31 (Martin 1999), introduced domestic caprines into their economy.

However, the Çatalhöyük settlement continued, and changes in various aspects of the material culture began to emerge, alongside the first indications of early cattle management. Nearby, Erbaba possibly had domesticated cattle from the outset, whilst both male and female domestic sheep were mainly culled for meat by three years old (Arbuckle & Makarewicz 2009). Interpreted as a seasonal herding–hunting camp, Pınarbaşı B was used

just as Çatalhöyük settlers relocated onto the nearby Çatalhöyük West mound. The evidence for reliance on domestic sheep (65%) and animal penning (Carruthers 2003) raises the possibility that Pınarbaşı B was a seasonal camp for Çatalhöyük herders. Throughout southwest Asia there is increasing evidence of milk exploitation moving from a subsistent role to a more central one (Rowley-Conwy 2000; Vigne & Helmer 2007).

The continuing success of Çatalhöyük was paralleled by increasing reliance on domestic sheep; domestic cattle were possibly now herded but did not contribute greatly to the economy and pigs remained a small hunted resource. The interplay of environmental pressures and social demands that made it possible for Çatalhöyük to maintain its sheep herding tradition is the research interest of this thesis.

CHAPTER 5. THE ÇATALHÖYÜK PALAEOENVIRONMENT

5.1. Introduction

The main locus of sheep herding, for the greater part of the year, would have been outside the Çatalhöyük settlement area on seasonal graze. When social needs, resource stress or climate extremes required animals to be penned or stalled, fodder would have been a pre-requisite; this too would have been located outside the settlement, to be collected and stored for later use. A central aspect of herding would have been knowledge of the location and seasonality of graze and fodder resources. The aim of this chapter is to construct a model of seasonal food resources available to domestic sheep herds around Çatalhöyük; it includes resources derived from an integrated arable–pastoral economy.

Herders would have needed to manage scheduled access to graze, not only to maximise nutritional returns, but also to limit outtake to sustainable levels, allowing pasture to recover for future years. The strategies used by herders to carry out these goals, and the extent to which they would have been successful depend, in part, on the status and integration of herding within the community.

Current research at Çatalhöyük reveals two areas of tension that might have led to lowered goal expectations. The first is the continuing celebration of hunting and the hunter, as exemplified in the art and installation. It suggests that herding domestic sheep and goats might have been a necessity but did not carry status. The second is that Çatalhöyük's location might have been limited in the amount of suitable land nearby, especially for arable farming. If this was so, then pastureland could have been redefined or relocated, and any

integration of the arable economy with herd resourcing carefully negotiated and tightly scheduled.

5.2. Present day environment

5.2.1. Topography

Today, the Çatalhöyük hinterland is the flat alluvial plain of the Çarşamba River (*Figure 3.1*). The plain forms the interior of the greater part of the Konya Basin, and is fringed by higher land. The Konya Basin, originally containing a palaeolake, has an undulating floor of Neogene marls sloping gently from 1020m in the southwest to 1002m in the northeast (Driessen & de Meester 1969). Associated shoreline features include the remnants of sand-spits, now interspersed with alluvium. These ridges are around the 1010m contour, 50–400m wide; and 5–20m higher than the marls (Driessen & de Meester 1969); the closest are 5km from Çatalhöyük. Around the basin, wave-cut cliff features in the surrounding Neogene soft-limestone terraces denote the lake edge (Leng *et al.* 1999). The terraces rise to 1200m (Cohen & Erol 1969); the nearest are 10km from Çatalhöyük.

Rising 1000m from the basin floor are remnant volcanic outcrops; Karadağ 40km to the south, and Karacadağ further east (Fontugne *et al.* 1999). The basin is fringed to the south by the upper cretaceous limestone Taurus Mountains, rising to more than 3000m, and to the north by the Palaeozoic limestones and schists of the Anatalides Range (Driessen & de Meester 1969). The nearest uplands are the Bozdağ Hills, which rise to 1500m, 30km to the north.

5.2.2. Climate

The climate today is best defined as very cold to cold, semi-arid Mediterranean (Nahal 1981). In Mediterranean climates the dry season is also one of maximum temperatures, where winter rain often falls in sporadic downpours, and where there is high inter-annual

monthly rainfall variability (Nahal 1981). Temperatures at Çatalhöyük can reach a maximum of 30 °C in July, dropping to -20 °C in winter (Fontugne *et al.* 1999); the mean range is from 23.5 °C to 1.4 °C (Roberts 1983). Most precipitation falls in winter and early spring as rain, or in the uplands as snow; it is derived from the Atlantic Ocean via the east Mediterranean (Leng *et al.* 1999). Rainfall averages 245.6mm on the plains and 1000mm in the uplands (Roberts 1983). In the basin, there is net evaporation of 800mm per year (Kuzucuoğlu 2002).

5.2.3. Hydrology

The basin is a closed system, fed mainly by rivers coming off the Taurus Mountains. Most of these waters evaporate in summer, but some go underground, in the Bozdağ foothills for example (Fontugne *et al.* 1999). Pınarbaşı, at the foot of Karadağ, is a karstic spring associated with re-emergence of ground-water through swallow holes in the centre of the plain (Leng *et al.* 1999). Periodic flooding, deriving from upland snow-melt and winter precipitation, is common in the late spring, and occasionally after high rainfall in late autumn and winter (Rosen & Roberts 2005). Nowadays, much of the basin is drained and irrigated, but towards the centre of the basin seasonal and permanent waterlogged, saline marsh areas remain, such as Hotamış (Driessen & de Meester 1969). Çatalhöyük is on a poorly drained area of alluvium, with heavy clays and a high water-table (Asouti & Fairbairn 2002).

5.2.4. Soils

Alluvial deposits now extend over much of the basin. Coarser sediments have been deposited by the fan on the flatter shores, whilst finer clays have been washed towards the centre of the basin and into local depressions (Driessen & de Meester 1969). The alluvial soils are fertile clayey loams, watered with perennial fresh waters on gradients affording some drainage (Driessen & de Meester 1969), particularly on the higher, sandier slopes. On

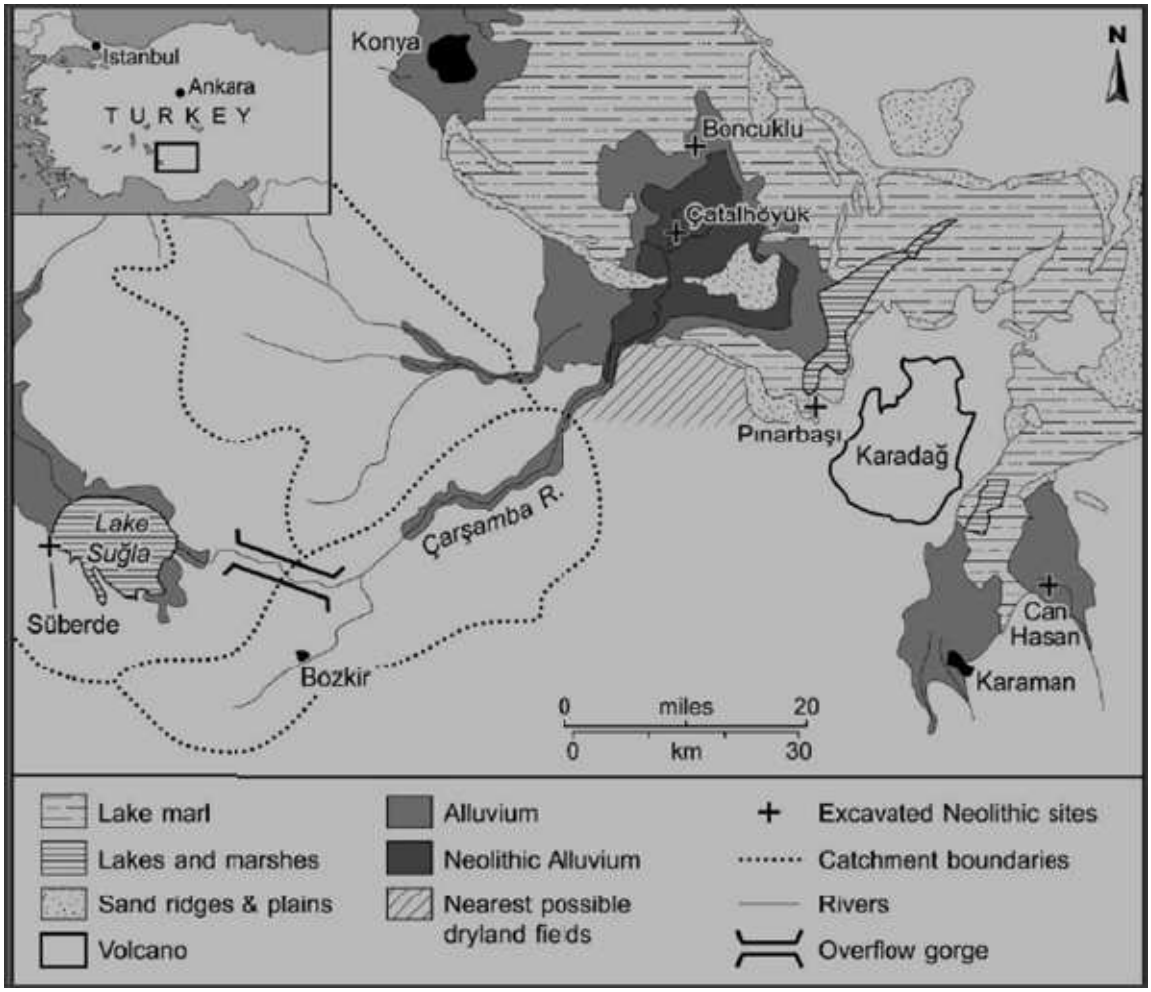


Figure 5.1
Geomorphological map of the western Konya Plain, Turkey. Map shows the extent of Çarşamba alluvium at the end of the Neolithic occupation of Çatalhöyük, c.*6200 cal. BC. Roberts & Rosen 2009, 394,* Fig. 1

the fan, there are waterlogged saline environments in the back-swamp areas, old river channels and on the fan's leading edge (Driessen & de Meester 1969).

Away from alluviation, the basin soils are 50–90% calcium and magnesium carbonates (Driessen & de Meester 1969). Net evaporation exacerbates the salinisation of these impermeable and nutrient-poor marls (Kuzucuoğlu 2002). The sand ridges are well drained, but have poor fertility, and the Neogene terraces have well drained, loamy soils (Driessen & de Meester 1969). The uplands and their slopes today have relic brown soils, associated with

earlier forest cover (Kuzucuoğlu 2002) and, apart from some pockets, the lithosols are generally shallow and stony.

5.2.5. Vegetation

The Mediterranean vegetation is in a transitional region between moist and arid, temperate and tropical, where palaeoclimate change and human impact have contributed to a continually evolving plant cover (Castri 1981). Increasing fertility produces more grass and soil impoverishment leads to more scrubland; increasing moisture produces more trees and greater aridity produces more shrubs (*Figure 5.2*). Human impact has either increased or reduced fertility, leading either to more grass or more scrub (Castri 1981).

Until the introduction of mechanisation, poor drainage on the alluvium discouraged its use for both arable and pastoral farming, so crop cultivation and semi-nomadic pastoralism were located on the terraces and sand ridges (Driessen & de Meester 1969). Today the fertile alluvial areas are drained for irrigated cereal and market-garden cultivation (Fontugne *et. al.* 1999). Non-cultivated areas of alluvium support degraded steppic plant communities, with rushes and reeds in relic marshes and lining irrigation channels, and salt-tolerant plants in heavily salinized areas (Driessen & de Meester 1969).

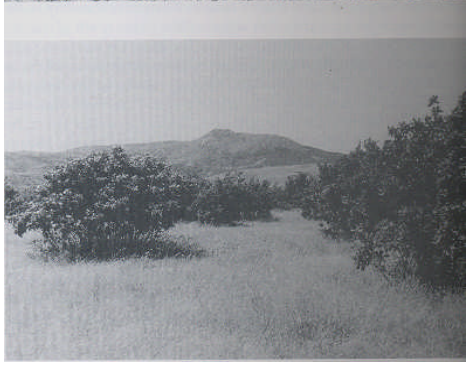
Today the terrace and hillslope vegetation is primarily xeric woody and evergreen shrubs (Castri 1981) (*Figure 5.2*). Open-parkland grasses have been overgrazed, leaving aromatic and spiny xeric perennials and annuals (Asouti & Hather 2001), and only more protected, well-drained areas still support species-rich grasslands (Driessen & de Meester 1969). The woodland grades with elevation and aspect from juniper–hackberry parkland, through oak parkland up to conifer forest; remnant open, evergreen-oak forests remain on the north-facing volcanic slopes of Karadağ, whereas pines, fruit trees and shrubs are more common on the south-facing limestone hills (Asouti & Hather 2001).

Chenopod – salsola steppe

Pistachio- almond parkland

Ungrazed *Stipa*

Grazed oak parkland



Ungrazed oak parkland

Fig 5.2
Examples of modern degraded vegetation zones, from photographs taken around Abu Hureyra, north Syria.
Hillman et al. *2001*

5.3. Neolithic Palaeoenvironment

In order to model the off-site exploitation choices made by Çatalhöyük inhabitants it is necessary to reconstruct a high-resolution local landscape, with a robust chronology; however, datasets used in reconstruction have different spatial and chronological resolutions, and carry inherent limitations in their interpretation. This section has been sub-divided into different topics, although the datasets under discussion are inter-related.

5.3.1. Climate

In *Chapter 7*, mid-Holocene global climate change and the prevailing Mediterranean and central Anatolian hydrology cycle are discussed in detail. In brief, evidence from Greenland ice cores identifies the progress of post-glacial warming in the Holocene (Darling *et al.* 2006, 14); Atlantic ostracod stable isotope values suggest the ocean atmosphere system controlled marine and terrestrial changes from arid to humid between 10000 and 7000 BP (Curtis & Hodell 1993); Mediterranean Basin cores indicate that central Anatolian weather trajectories broadly followed the same paths as today, with meteoric water originating in the Atlantic and passing over the Mediterranean (Emeis *et al.* 2000); the timing of sapropel formation in the east Mediterranean (Rossignol-Strick 1999) and Soreq cave speleothem evidence link warming events at sea with those on land (Bar-Matthews *et al.* 2003; Jones *et al.* 2007) (*Figure 5.3*).

In central Antolia, the timing and tempo of regional responses to Holocene climate change have been investigated using stable oxygen isotope, diatom, pollen and mineralogy evidence in sediment cores from Eski Acigöl, *c.* 200km east of Çatalhöyük (Roberts *et al.* 2001). As each dataset has independent response mechanisms to external forcing, Roberts *et al.* (2001, 727–730) argue that the synchronicity of responses could only have been induced by climate change, where the evidence points to a rapid increase in moisture.

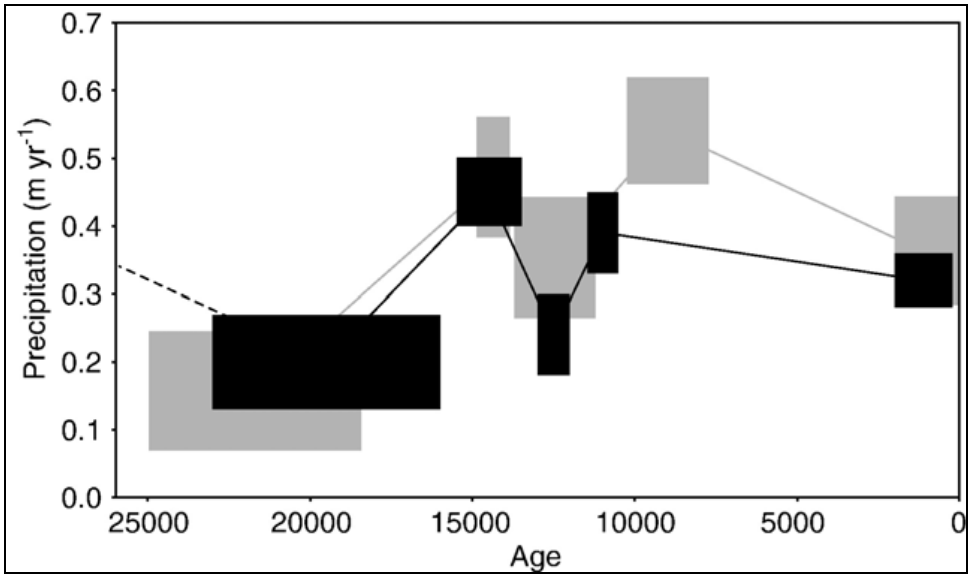


Figure 5.3
Comparison between the precipitation records from Eski Acigöl (black) and Soreq cave (grey).
Jones M. et al. 2007, 470, Fig. 5

Support is found in evidence from eastern Mediterranean sapropel (Rossignol-Strick 1999) and Lake Van varves (Wick *et al.* 2003). The Çarşamba fan initiation, dated to between 8000 and 7500 cal. BC (Roberts *et al.* 1999, 625), also indicates increasing humidity.

Climate amelioration during the Holocene proceeded to a maximum at 6500 BP (4500 cal. BC) (Kuzucuoğlu 2002), bringing wetter and warmer conditions to the Levant and central Anatolia. During much of the Neolithic occupation of Çatalhöyük the climate would have been warm, semi-arid to sub-humid, with 25% greater precipitation than today (Roberts 1991, 22). Climate models put mid-July temperatures 2.5 °C higher 9000 years ago (*c.* 7000 cal. BC) (COHMAP Members 1988, 1049). A brief reversal to a colder, more arid climate occurred *c*. 8.2k BP.

The seasonal distribution of precipitation has been investigated through pollen evidence of vegetation cover, where taxa-specific responses might indicate seasonal growing conditions. Pollen evidence from Eski Acigöl (Roberts *et al.* 2001, 732) (*Figure 5.4*), Lake Van varves (Wick *et al.* 2003, 670) and east Mediterranean sapropel (Rossignol-Strick 1999, 523) show

a rapid increase in non-arboreal grass pollens at the start of the Holocene, quickly followed by pistachio and other xeric trees, after which deciduous oaks and other broadleaf trees expand. However, mesic arboreal pollens do not reach their maximum until *c.* 6000 cal. BC, some 3000 years after temperature and moisture increased (Roberts *et al.* 2001, 730).

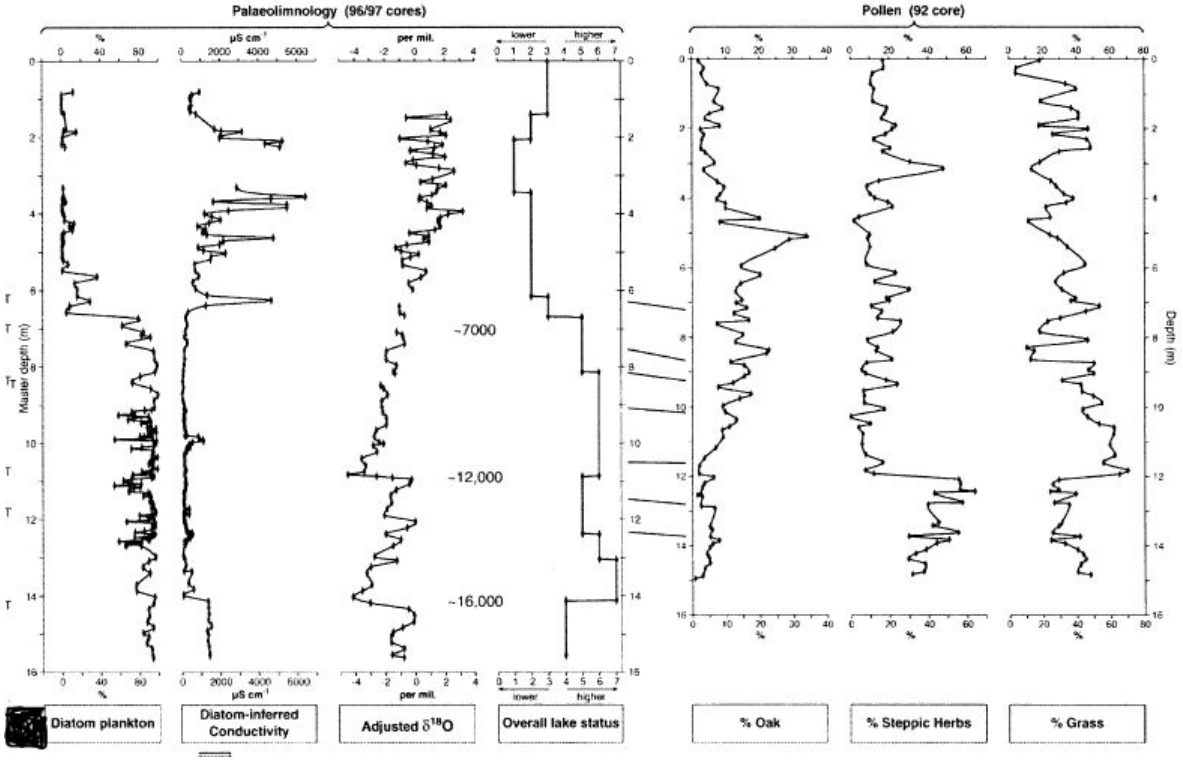


Figure 5.4
Synthetic diagram of Late Holocene environmental changes at Eski Acigöl, comparing selected palaeolimnological and terrestrial palynological indicators.
Roberts et al. 2001, 732, Fig. 7

The time-lag in the tree pollen maximum might reflect the geographical distance from Mediterranean *refugia* into the Anatolian interior (Roberts 2001, 1006). However, many woodland-steppe species, such as juniper, pistachio, hawthorn, wild plum and almond, are poor pollen producers (Woldring & Cappers 2001, 7), and it might be supposed their expansion was greater than the pollen record suggests (Roberts *et al.* 2001, 732). The early presence of juniper and oak is evident from the Çatalhöyük charcoal assemblages (Asouti & Hather 2001, 26).

The distribution of seasonal precipitation favours some species over others. Rossignol-Strick (1999, 528) suggests earlier pistachio dominance, confined to lower, more arid areas, is evidence of dry summers and humid, mild winters with average temperatures of 15 °C , none falling below 5 °C. She suggests that with increasing climate amelioration, oaks established on higher slopes where precipitation would have been higher.

In the second half of the 7th millennium cal. BC, the disappearance of frost-vulnerable plant pollen in pollen cores from northeast Greece is modelled as a >4 °C drop in winter temperatures on land (Pross *et al.* 2009). This date coincides with the '8.2ky event' and also with the abandonment of Neolithic Çatalhöyük.

5.3.2. Topography, hydrology and soils

The solid geology of the Konya Basin has remained unchanged since the Neolithic, and the soils and hydrology of the sand ridges, terraces and uplands would have been largely the same. Brown soil, associated with forest cover would have been less established and more restricted to higher hillslopes. However the landscape of the Konya Plain, and the extent of fertile alluvium, has altered considerably since the Neolithic. Specifically, the infertile, waterlogged marl would have been exposed on most of the plain, but is now largely covered by reddish, silty clay of the Upper Alluvial (UA) unit. At the time of Çatalhöyük's Neolithic settlement, fertile alluvium would have been restricted to small river fans (Boyer *et al.* 2006) (*Figure 5.1*).

Two cores from the Akgöl fossil shoreline (100km from Çatalhöyük) focus on the Holocene alluvial sequence in the Konya Plain (Bottema & Woldring 1984, 136; Roberts 1991). The cores show no evidence of marsh formation (Roberts 1991), however dating is insecure at the onset of the Neolithic (Bottema & Woldring 1984, 148). Using OSL (Optically Stimulated Luminescence) dating of dunes, as indicators of lake expansion and retraction,

Fontugne *et al.* (1999, 585) suggest the Konya Plain was largely dry and arid until the Bronze Age.

The Konya Plain Palaeoenvironment Project (KOPAL) was initiated, in part, to understand the dynamic alluvial environment on the Çarşamba River fan (Roberts 1982). Coring evidence from the on-site deep-sounding, the off-site KOPAL Area, and to the north and east of the site (Roberts *et al.* 1996, 23) identified a lens of organic dark clays covering the undulating marls, interpreted as early Holocene marsh formation (Roberts *et al.* 1996, 35). Above that, the light-grey, clay-rich Lower Alluvial (LA) unit was initiated just before the initial establishment of Çatalhöyük in 7480 cal. BC (Cessford 2005a).

Çatalhöyük was settled on the northeastern edge of the newly forming fan, probably on a higher marl area. Evidence of river gravels between Çatalhöyük East and Çatalhöyük West are interpreted as coming from a high-energy palaeo-branch of the Çarşamba River. Although the KOPAL cores reveal no levee formation on the Çarşamba palaeochannel, it is argued that, in an active fan, incision and lateral-channel formation would have formed an anastomising river system (Roberts & Rosen 2009, 394). Fine-grained clays in the Lower Alluvium are given as evidence of flood events and backswamp formation (Boyer *et al.* 2006, 689) which, over time, would have largely infilled marl depressions, reducing the mosaic of dry and marshy areas to one where widespread seasonal flooding was possible. Roberts and Rosen (2009, 396) describe Çatalhöyük as having been an island in springtime.

The current Landscape and Coring Programme took samples along a one kilometre east–west transect in order to test whether the KOPAL evidence had accurately been extrapolated to infer active alluviation over the greater part of the fan (Doherty *et al.* 2007, 382). Evidence of significant variability in the marl and alluvial stratigraphy over short distances suggests greater topographic variation than was previously thought (Doherty *et al.* 2007, 387).

A further series of cores and ditch-edge sections focused on the Çarşamba river channel just to the north of the site (Doherty *et al*. 2008). As an example, analysis of two cores (8 & 9) showed a depression in the marl which was only partially filled with LA before being covered with UA. Yet in other cores (1, 2 & 3) LA deposition was at much higher levels (Doherty *et al.* 2008, 266). Three interpretive points are made. Firstly, the evidence speaks of a small, stable, low-energy river system, only briefly gaining more energy between Çatalhöyük West and East. Secondly, the discrepancy in LA heights indicates highly localised transgressive events. Thirdly, where alluviation had not filled depressions, there would have been discrete bodies of water in the wet season rather than extensive flooding. Doherty *et al.* (2008, 266) argue that instead of interpreting the two alluvial units as temporally separate events related to climate change, a more consistent interpretation is that different, and concurrent, depositional environments account for differences in the two units.

Summarising the evidence from all core data, C. Doherty (*pers. comm.,* 13th July, 2009) suggests that the leading edges of the alluvial fan, close to the KOPAL Area would have been prone to flooding; to the west of the settlement there would have been ponds, marshy areas and possible flooding; but to the south there would have been a more extensive, dryer area on a large marl hummock.

The information from the second coring programme extends and refines the KOPAL model and provides a model of a Neolithic landscape less prone to flooding than previously thought, nevertheless, the environment was a depositional one, suggesting there was a significant amount of seasonal water. A seasonally flooded landscape might be reframed as one where there was a mosaic of un-flooded land, marsh and standing water, but nevertheless where there was enough water to recharge the depressions, and possibly to make un-flooded areas very damp.

5.3.3. Vegetation

This section provides a preliminary model of the likely vegetation distribution in the Çatalhöyük palaeoenvironment, in light of the topography, hydrology, soils and climate discussed above. At this stage, the human impact on vegetation patterns is not included, but this does not imply that the 'natural environment' acts as a backdrop to human activity.

In Mediterranean climates, aridity and cold winters are the prime limiting factors in vegetation growth (Nahal 1981), further limited by local soils and hydrology (Asouti 2005) and by the seasonality of precipitation. In his model, le Houérou (1977, 232) suggests that a cool, semi-arid climate would have a growing season of about five months, with two rest periods, one in winter where temperatures fall below 5 °C and the other in the arid summer period. In the proposed sub-humid climate of the Neolithic, warmer winters would allow a seven months growing season with only a summer rest period (le Houérou 1977, 232).

Çatalhöyük pollen evidence at a high spatial and chronological resolution is missing (Woldring 2002), and at Pınarbaşı, pollen cores only give Late Neolithic evidence (Bottema & Woldring 1984, 139). Further from Çatalhöyük, at Akgöl, pollen evidence is interpreted as indicating treeless steppe on the plain, with extensive grasslands on the terraces and lower hill slopes; riparian settings on the alluvium, terraces and lower slopes; xeric woodland competing with the grasses in better-drained areas, and a slow encroachment of mesic oak, juniper and silver birch woodland on higher slopes and pines in montane zones (Bottema & Woldring 1984, 131–136). The tree level could have reached 1400m on the southern slopes and 1100m on the northern slopes (Woldring 2002). The presence of halophytic chenopod pollen suggests increasing salinization, possibly as evaporative conditions dried out standing bodies of water on the plains and fans (Bottema & Woldring 1984, 147).

Working in northern Syria, Hillman (1996) adds detail to the model. Although this is a different environment, there are similar vegetation zones (*Figure 5.2*). The *Artemesia*-chenopod steppe would have been dominated by perennial *Stipa*-type tussock grasslands (Hillman 1996, 177), whereas there would have been a mix of annual and perennial grasslands on the terraces and lower hill-slopes. The xeric trees – pistachio, buckthorn, fruit and nut trees – would have been thinly scattered, remaining open for a long time (Hillman 1996, 187).

On-site archaeobotanic remains at Çatalhöyük (summarised in *Appendix 7*) add considerable information on plant taxa invisible to the pollen records, however datasets are limited to those species brought onto site by humans and their domestic animals (Fairbairn *et al.* 2005). Remains were retrieved from charred fire assemblages, mineralised penning deposits, silaceous casts of plant parts, mud brick inclusions and light- and heavy- sieved residues from depositional matrices (Fairbairn *et al.* 2005, 140; Rosen 2005). The most notable addition to the pollen record is the range of wetland taxa, including reeds, sedges, rushes, willows, poplar and tamarisk. Amongst these wetland plants good pasture grasses are likely to have flourished (le Houérou 1977, 258), including the perennial halophytic *Aeluropus* spp., also found in the Çatalhöyük assemblage.

Wild animal remains in the on-site zooarchaeological assemblage give evidence of their habitats in the Çatalhöyük locality (Russell & Martin 2005, 59). Wild cattle and horses inhabit grasslands, saline meadows and marshland, *Equus hemionus* are more restricted to grassland habitats, wild pigs choose riparian or forest settings, wild sheep and *Equus hydruntinus* inhabit open, dryer grasslands habitats, and deer select woodland settings. The balance of avian taxa indicates a range of extensive wetland habitats (Russell & McGowan 2005, 110), and the consistent presence of amphibian remains on-site suggests that the settlement was near wetland (Jenkins 2005; 2009, 202).

Four main vegetation units have been defined, based on palaeoecological interpretation of on-site assemblages (Asouti 2005, 244). These are riparian and marsh vegetation, woodland steppe vegetation, treeless steppe vegetation, and oak park-woodland.

5.4. Human impact on the environment

The record needs to be understood in terms of human impact (Kuzucuoğlu 2002) before further discussion. Palynological evidence of anthropogenic activities, such as *Plantago lanceolata* as an indicator of grazed grasslands or cereals as indicators of crop cultivation (Bottema & Woldring 1984, 148), does not appear in the regional record until the Bronze Age (Roberts *et al.* 2001; Woldring 2002). Yet Naveh (1990) describes how a co-evolution of Mediterranean people and their landscapes would have been in place from the Upper Palaeolithic onwards and, in the large Çatalhőyűk settlement, archaeological remains give evidence of wide resource exploitation of the soils, sediments, wild plants and trees, and of domestic crops and caprine herds from the time of initial settlement. The absence of this pollen evidence might lie in the fact that Holocene vegetation adjustments were not completed before significant human impact, and also because many domestic species were native to the region (Roberts 2002, 1003).

Goudie (1986, 26) describes four types of human environmental interference. Firstly, sporadic incomplete disturbance such as forest cutting, burning or non-intensive grazing results in degraded habitats. Secondly, sustained but unintentional vegetation changes, such as trackways, result in ruderal habitats. Thirdly, constant and deliberate planting, such as arable fields, results in cultivated habitats. Finally, an artificial habitat, such as a courtyard garden, is one completely created by humans. At Çatalhöyük, in the close vicinity of the settlement, the constant human activity and movement undoubtedly would have created a ruderal habitat. The archaeological evidence of domestic plants confirms cultivated habitats,

wood charcoals, domestic herd animals, and wild animal and plant remains suggest that much of the environment was degraded (*Table 5.1*).

5.4.1. Ruderal and cultivated areas

Cultivated habitats might be identified by crop remains and by weeds growing in association with the crops. Ruderal habitats include paths, field edges and fallow land as well as settlement-edge high-activity areas. Close to the settlement, the activities and movement of the community, especially clay extraction for mudbrick and ceramic production, is likely to have severely disturbed large areas, leaving only ruderal weeds growing. An ecological approach, FIBS (Functional Interpretation of Botanical Surveys), identifies the growth and survival habits of plants; these can be associated with different crop cultivation regimes and with ruderal areas (Bogaard *et al.* 2005). The use of FIBS should be used cautiously; it is unlikely that weed types and their habitats known in the Mediterranean today were the same in Neolithic, and so weed seeds might also indicate non-arable areas (McCorriston 1992, 90).

Charred remains of cereals and legumes, in various stages of processing, confirm that arable farming was practiced from the start of the Çatalhöyük settlement and underwent little change (Bogaard *et al.* 2010, 12; Fairbairn *et al.* 2005). Pulses have short growing seasons, and could have been planted in autumn or spring, but obligate eu-segetal weed seeds, found in association with wheat remains, indicate autumn-sown cereals, probably as vernalisation was necessary (Fairbairn *et al.* 2005, 177). Other weed seeds suggest crop cultivation took place in dry rain-fed conditions, rather than in those that were waterlogged or heavily irrigated (Fairbairn *et al.* 2005, 178). In support, parenchymous wheat remains were found to have small phytoliths, interpreted as markers of rain-fed dry farming (Roberts & Rosen 2009, 398). However, multi-cell phytolith forms, caused by high water-throughput typical of irrigated crops grown in arid regions, might be absent due to laboratory procedures (Jenkins 2009b).

	Cultivated and ruderal areas			*Degraded areas*			
Çatalhöyük locality	*Arable crops*	*Wild taxa*	*Weeds*	*Fruits and nuts*	*Fuel and timber*	*Grazing*	*Weeds*
Alluvial fan	Cereals, legumes	Oil seeds, club-nut tubers, rushes, reeds	Dry-farming crop weeds		Willow, poplar	Cereal and legume stubble, fallow and field edge weeds, wild grasses and meadow weeds	Dock, mints, wormwood, chenopods, spiny, aromatic plants
Plains					Wormwood	*Stipa*, *Aeluropus*	Mints, chenopods
Terraces	Cereals	Oil seeds	Dry-farming crop weeds	Hackberry, Pistaccio, cherries, plums, almonds, hawthorns	Hackberry, Pistaccio, cherries, plums, almonds, hawthorns	Cereal stubble, fallow and field edge weeds, wild grasses and meadow weeds	Dock, mints, spiny, aromatic plants
Hillslopes				Hackberry, Pistaccio, cherries, plums, almonds, hawthorns	Oak, juniper	Wild grasses and meadow weeds	Dock, mints, spiny, aromatic plants

Table 5.1
Çatalhöyük archaeobotanical evidence of plant exploitation associated with human interference of the landscape.
After Fairbairn et al. *2005*

Crop rotation might have been practiced in order to build moisture and nutrient levels in the soils, after wheat harvests in particular. Fallow fields might constitute one half of the cultivated environment, although there is no archaeological evidence of this. Comparing empirical data from different parts of the Konya Basin, Janssen (1972, 259) argues that fallow rotation can effectively store moisture, and that this, rather than nutrient replacement, is crucial in 260–350mm isohyet rainfall regions. However, cutting down weeds to break their annual cycle, or for animal fodder, reduces moisture-retaining advantages (Palmer 1998, 148). In north Jordan, traditional methods include long fallowing from cereal harvest to cereal planting over one year later, and short fallowing just until legume planting seven or eight months later (Palmer 1998, 149).

In late autumn, the cultivated landscape could have included tilled fields. Tilling breaks up the soil before annual weeds have established and is done in time to allow deep penetration of seasonal rain and, consequently, less evaporation (Palmer 1998, 149). Sometimes small numbers of sheep are put on newly germinated crops for a short period to clip the tops of cereal shoots; this encourages underground rooting, or tillering, and holds back growth that might otherwise make plants vulnerable to lodging in wet or windy weather (Bogaard 2005, 180).

After harvesting cereal crops in summer, stubble might have been left in the ground over winter to hold snow, as in Çumra until recently, pulled up and dried for fuel (Jansen 1972, 253), or used for grazing domestic herds, as is so common today. The Çatalhöyük weed-seed evidence suggests that crops were reaped close to the ground, but straw remains are almost absent from the archaeological record. It was suggested that they were used in brick making (Fairbairn *et al.* 2005, 180), although preliminary studies find only chaff remains (Bogaard *et al.* 2008). Legumes are more likely to have been harvested by pulling plants out at the roots (Palmer 1998, 150).

The trackways and field edges of cultivated areas tend to have ruderal weed species which can retreat or quickly recover from disturbance. At Çatalhöyük, assemblages of oil-rich *Capsella* and *Erysimum* seeds in a Level VII storage bin could have been gathered from an uncultivated or ruderal area (Fairbairn *et al.* 2005, 139), and assemblages of wild grasses such as *Taeniatherum* and *Eremopyrum,* possibly used for basketry, might indicate ruderal or undisturbed areas (Fairbairn *et al.* 2005, 139). In the archaeobotanical assemblage, many weed seeds associated with ruderal, cultivated and undisturbed habitats are assumed to have been eaten by domestic herd animals, partly as these plants no longer provide edible green leaves for humans once they have seeded, and partly as they are often found in contexts rich in dung fuel or penning deposits (Fairbairn *et al.* 2005, 175). In north Jordan, soft leaves of

Convolvulus are collected for young animals (Palmer 1998, 149), and any wild grasses are harvested and dried (Palmer 1998, 160).

The location of Çatalhöyük's cultivated areas is debated, partly resting on conflicting models of the alluvial hydrology, and partly on models that propose extensive farming versus garden farming, or a historically contingent combination of both. Roberts and Rosen (2009) put forward a model based on an interpretation of extensive seasonal flooding on the alluvial fan where conditions would have been too wet for winter- or spring-sown cereals, or for sheep herding; they propose extensive landscape use, involving the seasonal fissioning of the population to work locations on the terraces. The fan environment in this model would have been relatively undisturbed and rich in wetland plants, whereas cultivated and ruderal habitats would have been more widespread on the terraces.

If there were more extensive dryer areas on the alluvium (Doherty *et al.* 2007; 2008) highly integrated garden agriculture might have been practiced (Bogaard 2005), where small arable plots, using pulse–cereal crop rotation, were weeded and manured, and where small domestic herds were grazed on field-edges (Halstead 1996). Undisturbed areas of dry-land grasses and xeric tree species, as well as riparian vegetation might have been cleared for cultivation. In the dampest locations, tree clearance would have allowed the colonisation of invasive wetland plants, such as *Phragmites,* used in basketry, roofing and matting (Ryan 2010), or *Bolboschoenus maritimus* tubers, possibly used as human or animal fodder (Fairbairn *et al.* 2005, 140). It is possible that arable plots would have needed to be highly dispersed over dryer areas of the fan; this is a high-risk strategy, prone to low yields and failure in years of bigger floods (Asouti & Fairbairn 2002). In this model, the extensive grasslands on the plain, the terraces and hillslopes would not have been used for grazing domesticates.

Fairbairn (2005) suggests that the mosaic of dryer areas on the fan could have supported intensive garden farming in the early phases of occupation at Çatalhöyük, but that as the population increased, and as alluviation brought more widespread flooding, farmers would have incorporated into their repertoire less intensive arable farming on the dryer terraces and sand ridges.

5.4.2. Degraded areas

Although the word 'degraded' is used, deliberate human activity might have been perceived as enhancing the environment. The goals demanding landscape interference vary widely; hunter-gatherers, for example, might fire grasslands in autumn to promote hunting, but herders would not want this as it would curtail the grazing season (McCorriston 1992, 138).

The woodland–grassland mosaics of the dryer fan areas, terraces and hillslopes fall into the savannah category, described as a two-phase mosaic where woody plant clumps exist in a continuous grass matrix (Scholes & Archer 1997, 518). Savannahs that are lightly grazed and periodically fired are considered very robust habitats, able to make easy short-term local changes but with long-term wider stability (Scholes & Archer 1997) in response to all but the most severe external pressures (Goudie 1986).

There are different types of interference that cause degraded habitats. Tree clearance and exploitation, vegetation firing, and domestic herd grazing are the main forms of human activity that might alter the woodland–grassland balance. The effects of such interference are greater where there is more biomass to degrade (Wiens 1985, 172), as might have been the case during the Neolithic, when the environment was richer and its mosaic nature more marked (Lancaster & Lancaster 1991).

Fires naturally occur every 10 to15 years in parkland areas, increasing to every 5 years in more steppic grassland areas of Mediterranean parkland (Goudie 1986, 31). Fires help seed

germination, improve the soil, control pests and encourage species diversity (Goudie 1986, 29). They favour perennial grasses which have protected underground root systems (Scholes & Archer 1997), whereas annuals are at greater risk as their seeds get burnt (McCorriston 1992, 139). *Stipa*, originally restricted to locations near water, would have spread quickly with firing (Hillman 1996, 177).

Grazing, if it is light, removes the toughest perennials and encourages new growth; dung provides quickly released organic nutrients, a method of seed dispersal and a good seed bed, and trampling helps seed germination and opens up soil for new species colonisation (Goudie 1986, 34). Sheep return between 10–70% of the grazed biomass as dung (Andrzejewska & Gyllenberg 1980). Low stock intensity is a more effective mechanism for grass regeneration than any rotation system (van Poolen & Lacey 1979).

For grazing to be beneficial it must be timed to allow seasonal plant growth. Annuals need winter rain to germinate whereas perennials need spring rain but also have another growing season stimulated by heavy dew in early autumn (Lancaster & Lancaster 1991). Grazing in late spring and early summer eliminates taller annual grasses, especially in dryer areas, and only shorter grasses, which seed rapidly, remain (Hillman 1996, 197). Year-round repetitive grazing also eliminates perennials such as tussock grasses; again leaving lower-growing grasses (Hillman 1996, 197). As sheep graze close to the ground (Andrzejewska & Gyllenberg 1980) these seasonal grazing effects would improve grazing quality on both the plain and the grasslands of the alluvial fan and hillslopes.

However, domestication removes animals from many constraints of natural selection (Hurtchinson & King 1980) and, if numbers had increased rapidly in the Neolithic, the impact of grazing on the vegetation might have been considerable. If temperatures remained above freezing in Neolithic winters, grass would have continued to grow above 5 °C but, as herds might not have needed penning, there would have been no recovery time for the

pastures (le Houérou 1981). When dry, over-stocking exposes dry soils to wind erosion, and when wet, soil impaction causes anaerobic conditions unsuitable for plant growth (Goudie 1986, 35). Waterlogging brings worms and their casts to the surface, exacerbating the poaching effects of over-stocking (Healy and Ludwig 1965). Heavy grazing kills plants, and encourages resistant unpalatable plant growth (McCorriston 1992). In the Californian chaparral, over-grazing encourages progressively less desirable grasses, culminating in *Taeniatherum* spp. and *Aegilops* spp. (Goudie 1986, 35); these species are found in the Çatalhöyük assemblage (Fairbairn *et al. 2005,* 142) along with increasing numbers of unpalatable spiky or aromatic herbaceous plants (Asouti & Hather 2001, 27).

Collection of firewood, timber and browse-fodder, and the conservation of resource-producing trees might also have degraded the vegetation landscape. Coppicing stunts growth (Scholes & Archer 1997) and generates thick scrub which replaces tall trees (Asouti & Hather 2001), and goats destroy young bushes and saplings, reducing available firewood and timber (Köhler-Rollefson & Rollefson 1990). The modelled firewood need is 1.5kg dry wood/person/day (le Houérou 1981), and thus constitutes a large resource requirement. Çatalhőyűk archaeobotanic evidence indicates that oak and juniper were preferred for timber, but that most firewood came from riparian and woodland steppe tree species (Asouti 2005; Fairbairn *et al*. 2002). Weed seeds and phytoliths of deciduous leaves, found in penning deposits and charred dung-fuel, are interpreted as evidence of browse fodder (Fairbairn *et al.* 2002; Rosen & Roberts 2005). Layers of twiggy remains have been found at Çatalhöyük; it is suggested that these could have been collected first for their fruits, then for leaf fodder, with the twig remains then used as kindling (Rosen & Roberts 2005).

Changes in wood exploitation are the exception to the general picture of unchanging plant cultivation and use during the Neolithic settlement at Çatalhöyük (Faribairn *et al.* 2005, 192). Dung fuel, found throughout the occupation at Çatalhöyük, is more predominant than riparian tree charcoals in the earlier sequence whereas, in later levels, the dung persists but

oak and juniper charcoal becomes more frequent (Asouti & Fairbairn 2002). Fairbairn *et al.* (2005) argue that the evidence suggests that at no time was the wood fuel supply adequate, and that an initial depletion of limited oak sources soon after the first settlement led to the use of riparian trees, although an inferior fuel. Wider landscape exploitation, moving to mesic species on the hillslopes, became necessary in later phases (Asouti & Hather 2001).

Stable carbon isotope signatures in human and domestic mammal bone (Pearson *et al.* 2007) indicate that Çatalhöyük inhabitants moved further out into the landscape over time, either to graze herds or to collect fodder. Evidence suggests that sheep, but not goats or wild cattle, had a more varied diet that included C4 plants such as *Aeluropus* spp. and *Salosa* sp., in Level PreXIIB than in earlier levels (Pearson *et al*. 2007, 2173). Finally, on-site zooarchaeological evidence of a decline in red deer, wild boar and equids might indicate anthropogenic changes to their habitats that caused them to retreat to more distant locations (Russell & Martin 2005, 59).

5.5. Summarising the Çatalhöyük palaeoenvironment

It appears that the warm, moist climate during the Neolithic of central Anatolia brought an expansion of fertile alluvial fans and extensive grasslands over the Konya Plain, and increasing numbers of xeric and mesic trees in grassland savannahs on the surrounding terraces and steeply rising mountain slopes. These habitats would have supported a range of wild plants and animals.

Çatalhöyük was settled in an optimal location for growing crops and grazing domestic herds where it was neither too arid nor too densely forested, and where there was access to a range of wild resources (Roberts 2002). The steep topographical gradient at Çatalhöyük would have provided the opportunity for herding and arable farming to have spread through the ecological grass zones, away from the fertile fan around the settlement, onto the terraces and

up into the hills (Fairbairn *et al.* 2005). The question for palaeoenvrionmental reconstruction is – did any such expansion take place?

Palaeoenvironmental reconstruction cannot ignore, or separate, the effects of anthropogenic activity (McCorriston 1992). Even if the alluvial fan hydrology had only brought intermittent, localised flooding around Çatalhöyük, land available for any activity, including mixed garden agriculture, could still have been limited and likely to have been under stress from the demands and activities of an estimated population of 3500–8000 (Cessford 2005b). If there was intensive garden farming on the fan, much of the dryer areas would have been under cultivation, bringing crops and their by-products to the resource pool, but reducing field edge habitats to ruderal weed vegetation. Overall, grassland availability on the fan would have been reduced. Fuel collection and arable land clearance might also have increased the extent of wetland reeds on the alluvial fan.

The evidence suggests that Çatalhöyük settlers were spreading into the wider environment for a number of resources, including woodland exploitation. If the fan hydrology was such that arable farming had to expand into dryer areas, the sand ridges further up the fan might have provided enough arable land to feed 5000 people without recourse to the hills (Donovan 2005). However, the terraces, slightly further away, could have been more attractive because of their well-drained, fertile soils (Roberts & Rosen 2009). If herding had spread into the wider landscape, suitable extensive grasslands existed on the plain, the terraces and the hills.

More extensive agriculture on the terraces could have had less impact on the grasslands as the terraces were more extensive than the fan. Fuel collection and agricultural clearance could have served to keep the woodland encroachment at bay and grasslands open (Roberts 2002, 1006; Woldring 2002). Depending on stocking pressures and grassland management practices, such as seasonal firing, the grasslands might have expanded further, or might have

been replaced by unpalatable herbaceous shrubs that forced herders further up the slopes (McCorriston 1992).

Figure 5.5 presents a model of the Çatalhöyük landscape during the Neolithic, based on the evidence and discussion in this chapter. It serves as the first step in a model of the seasonal management and movement of herds to food resources. In *Chapter 6*, the ethology of sheep and the ethnology of sheep herding is discussed, leading to a more closely defined model of seasonal resources suitable for domestic sheep herds.

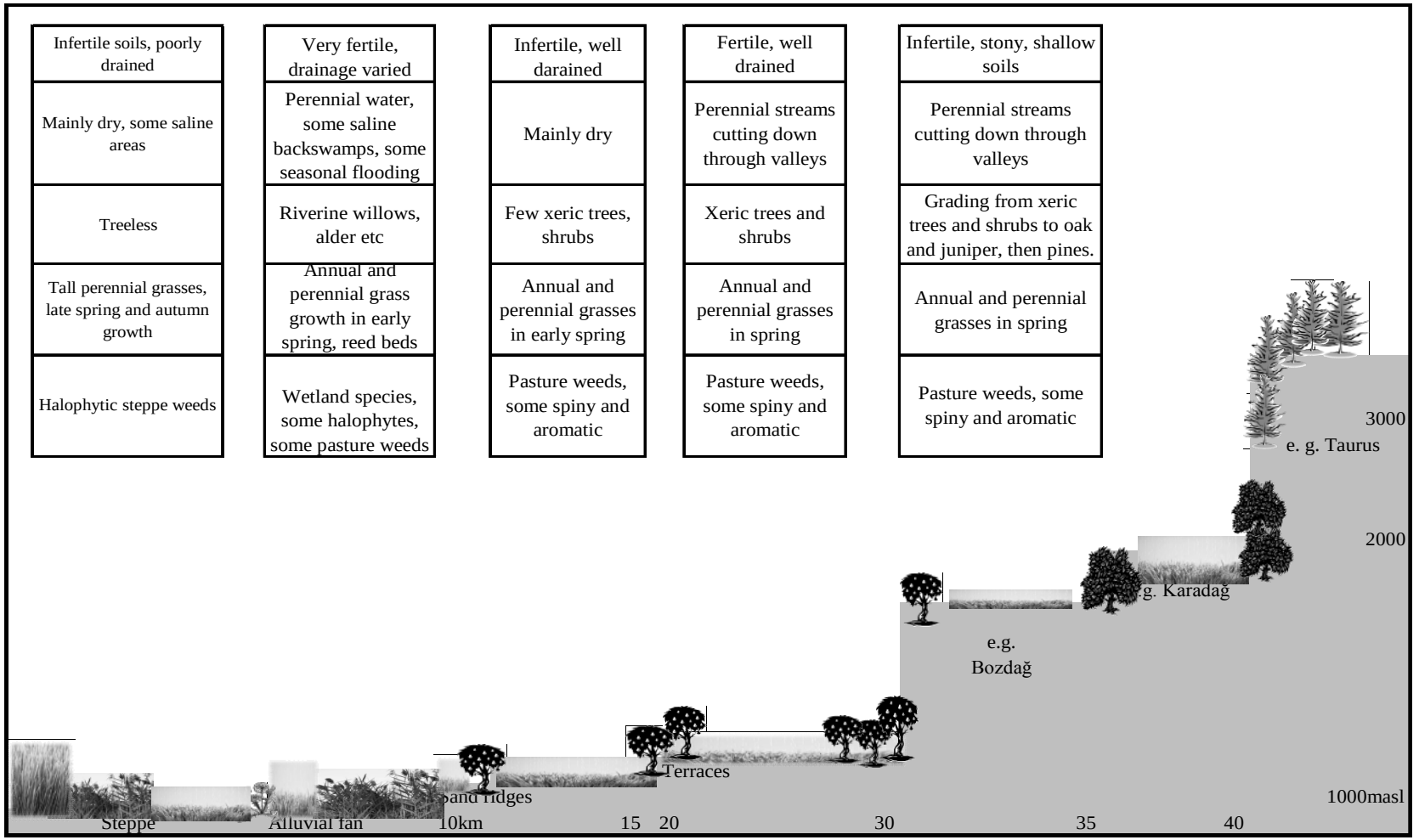


Figure 5.5
Model of Çatalhöyük landscape showing possible vegetation distribution in the Neolithic

CHAPTER 6. THE ETHOLOGY OF SHEEP AND AN ETHNOGRAPHY OF THEIR HERDING

6.1. Introduction

Above all else, herders need to understand their sheep, so that they establish the conditions of growth needed for herds to thrive. This chapter considers sheep behaviour and their ecological niche, and reviews how both have been varied safely and usefully by domestic breeds and their herders. An underlying tenet of this thesis is that both sheep and herders are aware of the best husbandry practices, and any deviation from optimal conditions needs contextual explanation.

It is not the purpose of this chapter to formally model sheep behavioural ecology, in terms of optimal foraging strategies or resource patchiness models, for example. Models of phenotypic variability might usefully describe the adaptive range of wild animal behaviour in native habitats, but continuity of conditions and resources is not necessarily found in the dislocation between native habitats and anthropogenic herding settings. Niche construction theory allows a more flexible approach to how sheep construct niches out of the bits and pieces of their world, as limited by herders, so that they can survive even in inhospitable environments (Smith 2007).

Sheep biological drives are discussed in turn using a combination of evidence. Biological research on the ethology of wild sheep is compared to agricultural and veterinary evidence relating to domestic forms. Discussion of each category continues with a more anthropological slant, where indigenous knowledge is added to scientific knowledge. Niches that have been constructed for domestic herd animals are also partly inhabited by their herders, and the later sections draw on ethnographic information to consider the manner in

which herders' lives are entangled and defined by their work. Throughout this chapter, *Table 6.1* provides further environmental or ethnographic background to the wild and domestic herds that have been cited.

Each dataset has limitations when used to elucidate, by analogy, prehistoric herding practices. Ethological evidence is predicated on unresolved taxonomic detail, and takes its evidence from wild sheep living in restricted environments, where behaviour might no longer be 'pristine'. Agricultural sciences work with modern sheep breeds that are often behaviourally and physiologically very different from early domesticates. Observations on sheep behaviour made by scientists might be over-emphasised compared to those made by indigenous herders, although indigenous knowledge has no less validity and might often have more relevance (Pierotti & Wildcat 2000). In general, the ethnographic literature on herding is of limited value to this thesis as it largely focuses on either nomadic pastoral societies or on small settled village communities who raise their herds primarily for milk (*Table 6.1*), whereas the evidence presented in *Chapter 4* suggests that Çatalhöyük was a large community, where meat and fat goals might have had the greater influence on herding strategies.

6.2. Evolution and zoogeography

6.2.1. Evolutionary history

Sheep (*Ovis* spp.) are ungulates belonging to the order Artiodactyla, suborder Ruminata, infra-order Pecora, and family Bovidae (Ryder 1983, 4). Ungulate evolutionary history is discussed in *Chapter 8*, but in brief, sheep digestion and locomotion are considered to have evolved to efficiently occupy grassland habitats (Geist 2000, 186; Gentry 2000, 11). In comparison to other ungulates, sheep are small bodied but have a higher metabolic rate; their diets require relatively less fibrous bulk and more protein (Sinclair 2000, 251).

	Seasonal movement	*Product goals*	*Species*	*Breed or sub-species*	*Habitat or herding area*	*Altitude masl*	*Climate*	*Vegetation*	*References*
Wild or feral animals	Upper to lower hills	X	*Ovis orientalis*	*O. o. anatolica* Bozdağ	Enclosed reservation on the edge of Konya Plain, central Anatolia	1000–1735	Semi-arid Mediterranean	Rolling hills, steppe ecotones	Kaya & Aksolar 1992 Kaya *et al.* 2004
		X	*O. Canadensis*	*O. c. canadensis*	Rocky Mountains, USA & Canada	*c.* 3500	Alpine	Short growing season	Lenarz 1979
	Vertically, on mountains	X		*O. c. nelsoni* Desert bighorn	New Mexico, USA and Mexico deserts	2550	Desert	Steppic lower, pine grassland upper	
Herders			*Domestic*						
Qashqa'i	Nomadic pastoralism	Milk products	*Ovis aries*	'Nomadic' breed	SW Iran, Fars, Highland and lowland Zagros Il-rah 350 miles, 5-6 months	600-4000	Semi-desert lowlands	Poor winter lowland pasture, good spring low and mid-altitudes, good summer high altitudes	Beck 1980, 1981
Basseri									Barth 1959-1960; 1961
Yomut Turkmen		Meat, fat		Fat-tailed breed	Turkmenistan, Iran	150-3000	Arid sub-tropical desert	Steppe	Dahl & Hjort 1976
X	Vertical transhumance, from 3 bases	Milk products	*Ovis aries*		Turan, Iran	1000–1600	Semi-arid		Nyerges 1980
Lakenkhel	Vertical pastoralism		*Ovis aries*		NW Afghanistan	3000m summer pastures	Arid to semi-arid		Balıkcı 1990

Table 6.1
Additional details relating to the environment of wild and herded sheep cited in Chapter 6

Herders	*Seasonal movement*	*Product goals*	*Species*	*Breed or sub-species*	*Habitat or herding area*	*Altitude masl*	*Climate*	*Vegetation*	*References*
Fallahin	Mixed agriculturalists	Milk products	*Ovis aries*		N-W Jordan	373-1150	Sub-humid & semi-arid Mediterranean	Spring graze and summer crop stubble, hay fodder	Palmer 1998
X			*Ovis aries*	Karakol, Merino	Central Anatolia	1000	Cold semi-arid Mediterranean	Village edge grazing, winter stubble	N.Kayan & M. Sivaş, *pers. comm.*, July 2007
Turkana	Nomadic horizontal transhumance, some settled	Milk, meat and wool products	*Ovis aries* D		NW Kenya, E. Africa	*c.* 400	Arid to semi-arid	Dry savannah	Little & Leslie 1999; Mace 1993
Navajo	Vertical transhumance	Wool	*Ovis aries*	Churro	Colarado, USA	2000-3500	Arid	Steppe - desert	Bailey 1980
Languedoc	Vertical transhumance Mt. Aigoual	Dung and wool, castrates		Raiole	Cévennes National Park, Languedoc	1200-1500	Mediterranean winter & spring area, Oceanic in summer	Following grass growth	Grellier 2006
X	Mixed agriculturalists	Young lamb and milk	*Ovis aries*		Macedonia, N.Greece	400	Mediterranean	Oak shrubland	Papachristou 1997
Raika	Mixed long migration and local herding	Meat (some dung and wool)	*Ovis aries*	Drought resistant, long-distance walking	Rajasthan & Gujerat, India	60-500	Semi-arid	Steppe, migrating to forest edges of hills	Geerlings 2004

Table 6.1 cont.

Wild sheep extant near Çatalhöyük, (*Ovis orientalis anatolica*, Valenciennes 1856) (*Figure 6.1*) are considered to be a mouflon type, based on horn morphology, coat colouration, and chromosome pattern (Kaya *et al*. 2004); mouflon native habitat currently extends from western Turkey to Baluchistan and from the Caucasus to Sinai (Uerpmann 1996, 233). Estimates of clade-expansion timing suggest that an explosion of sub-species populations occurred before domestication (Meadows *et al.* 2007), and that *O. orientalis anatolica* might be one remnant sub-species population (Bruford & Townsend 2006).

Figure 6.1
Wild rams on the Bozdağ Wild Sheep Reserve near Çatalhöyük

Of the three wild Ovis species, *O. orientalis*, *O. vignei* and *O. ammon*, only *O. orientalis* has the same diploid number (2n-54) as modern sheep, *O. aries*, and is considered to be the ancestor of domestic sheep (Hiendleder *et al.* 1998). Archaeological evidence of the earliest domestic sheep within the *O. orientalis* habitat provides zoogeographical support. A number of domestic clades, that can be associated with the region, derive from *O. orientalis*, possibly from sub-species that are no longer extant (Bruford & Townsend 2006).

All forms have considerable genetic plasticity and are able to interbreed (Geist 1971; Schaller 1977); the long history of hybridisation and feralisation does little to help resolve

conflicting evolutionary evidence (Ryder 1983, 20). There is recent historical evidence of wild rams mating with modern breeds of domestic ewes on the Konya Plain and in the Zagros Mountains (Aydinoğlugil 2000, 18; Watson 1979, 18), and it is likely that this was more widespread in the Neolithic. For the purposes of this chapter, the plasticity between wild and domestic types suggests that ethological evidence from wild sheep has considerable relevance for domestic sheep, particularly in the Neolithic of southwest Asia.

6.1.2. Effects of domestication

Sheep are one of the few species that fulfil desirable requirements for easy and useful domestication whilst not being caused undue stress by domestic herding (Garrard 1984). They are highly specialised to release proteins from complex plant cellulose carbohydrates indigestible to humans, turning them into high-yielding meat, fat and milk products palatable to humans (Hofmann 1989, 443). Their open grazing habitats are easy for herding, and they live gregariously in fairly large, hierarchically organised herds where herders can enter the top of the hierarchy (Garrard 1984). Herd size and birth-rate allow large quantities of products to be available to the community (Garrard 1984) and the mother–lamb interaction and natural subdivision of herds by age and sex classes are the very attributes that herders wish for in domestic animals (Russell 1998, 20).

This research focuses on sheep that were already domesticated at the time of settlement at Çatalhöyük, but it is worth briefly reviewing some pertinent points about the process of domestication. The behaviour of domestic animals is less determined by environmental factors than that of wild animals, due to an innate reduction in environmental awareness; social cohesion, mobility and flight distance all decrease (Hemmer 1990, 92). Ethological responses to population-density stress, such as declining body size and delayed or repressed sexual maturity and fertility are also weaker in domestic animals (Hemmer 1990, 93–96). The basic physiological processes associated with survival, such as feeding, moving and breeding, remained essentially unaltered on initial domestication (Russell 1998).

Sheep are able to adapt both physiologically and behaviourally to restrictions imposed on them by their environment (Geist 2000, 180); such adaptations can take sheep to the margins of survival, where thriving becomes a riskier business (Hofmann 1989, 444) (*Figure 6.2)*. Innovations in husbandry practices entail experiments in pushing limits, and weighing advantages against costs.

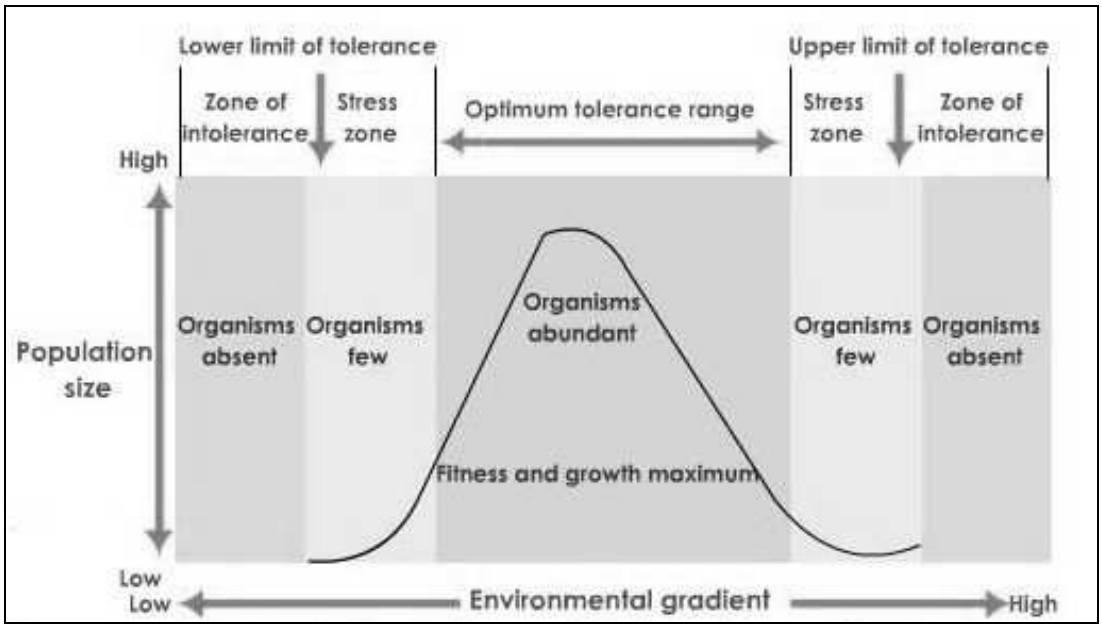


Figure 6.2
The response of an organism to a range or gradient of an environmental factor. Hoffman 1989, 444

The first domestic sheep herding took place in the natural habitat of their wild progenitors, so not only were sheep being managed in habitats in which their wild forms thrived, there was also opportunity for herders to learn from the natural patterns of seasonal movement, birth, herd splitting and feeding behaviour (Hole 1978, 139).

6.2. Feeding and drinking

Ungulate herbivores are divided by forage preferences, and accompanying physiological and morphological adaptations, into browsers, mixed feeders and grazers (*Figure 6.3*). Palaeontological evidence suggests that grazers first evolved to utilise the grass niche found

in light, woodland under-canopies (Janis *et al.* 2004, 379). Sheep and goats have overlapping habitats and occupy different niches (Landau *et al.* 2000, 41), with most sheep species occupying grassier habitats. Domestic sheep are often described as mixed feeders because of their adaptability, but their preference and high physiological and morphological specialisation for grazing more correctly place them in the grazing category (Hofmann 1989, 445).

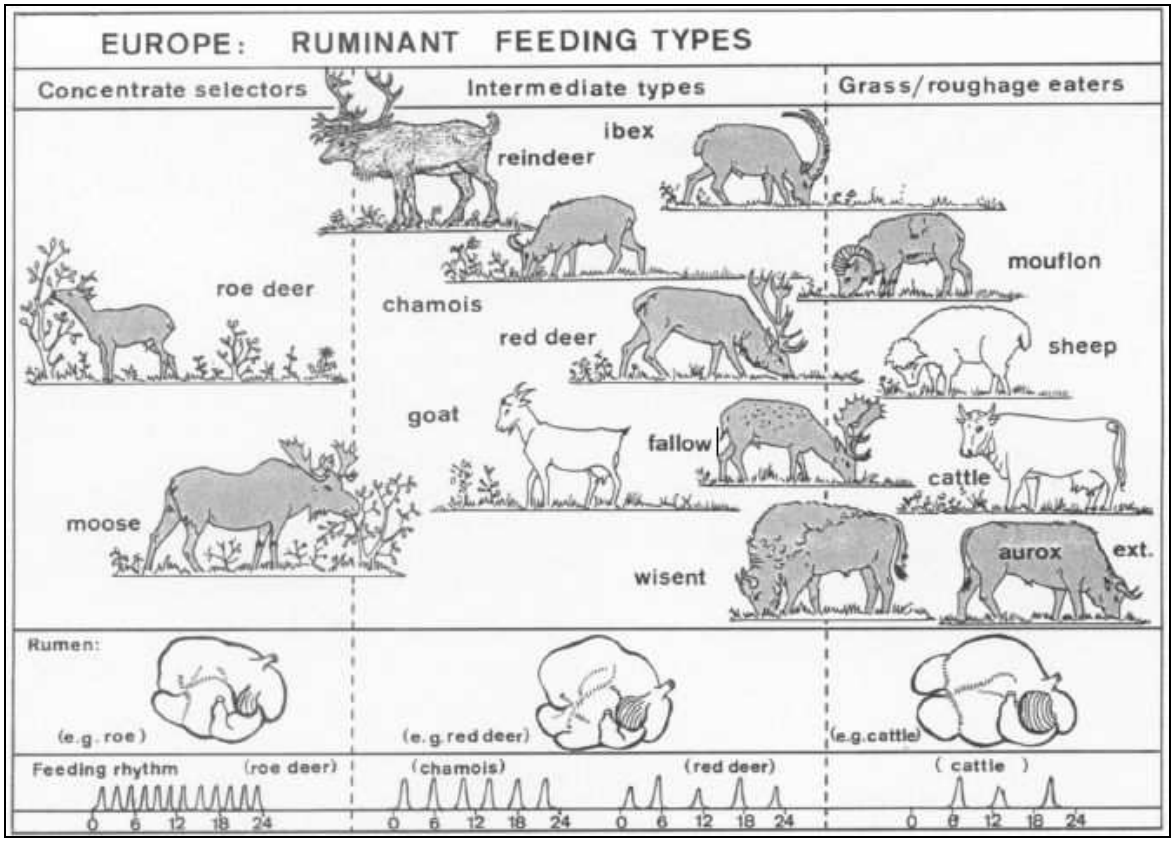


Figure 6.3
Feeding behaviour of ungulate herbivores.
Hofmann 1989, 445

The availability and nutritional value of graze is a function of seasonality and latitude, where the condition of wild sheep can vary throughout the year. This largely underpins other behavioural characteristics, such as breeding and movement. However, the seasonal condition of domestic sheep can be overridden by controlled feeding, such that those

targeted for fattening-up or breeding might be given highly nutritional food out of season, whereas fallow herds might be confined to low-maintenance pasture or fodder.

6.2.1. Food ingestion and digestion

Mouth structure and dentition (*Chapter 8*) enable wild and domestic sheep to graze on pastures dominated by short, green grasses and interspersed with ground-hugging, non-woody annuals and perennials (forbs). Their thin, bifurcated, muscular lips allow sheep to manipulate the foliage, selecting leaves over stems and young, green shoots over dead or woody material (Anderson & Ertuğ-Yaraş 1998, 103; Grant *et al.* 1985, 992; Kaya *et al.* 2004, 231; Sinclair 2000, 253).

Sheep have three major foregut chambers, evolved to manage the regurgitation, fermentation and digestion of cellulose-rich grass diets (Gentry 2000; 12). The process of rumination – regurgitation, re-chewing and re-swallowing – breaks up the cell walls enabling microbial fermentation of plant cellulose in the rumen; this produces fatty acid waste products digestible to sheep (Gentry 2000, 12). In sheep, this typically takes place in a diurnal rhythm of long feeding periods interspersed with long spells of rumination and rest (Hofmann 1989, 445; Ryder 1983, 678). Adult rumination on an established diet can result in up to 80% digestive efficiency, but lambs build up the required bacteria slowly and all sheep have to build new bacterial communities when their feed radically changes (Hofmann 1989, 453).

Microbial fermentation has two drawbacks; firstly, it is a lengthy process, where food particles >0.5mm in diameter are trapped in the rumen limiting new food intake (Hofmann 1989, 447). Longer periods of rumination are required for more fibrous food (Ryder 1983, 678), such that on very high fibre diets the rate of digestion is so slow that the animal can starve (Janis 1976, *cited by* Anderson & Ertuğ-Yaraş 1998, 102). Secondly, there is a heat output associated with the fermentation of highly fibrous foods, which is warming in winter but exacerbates overheating in high ambient temperatures (Silanikove 2000, 95). In arid-

regions, wild sheep avoid overheating by eating less in summer (Silanikove 2000, 95), but the high productivity demanded of domestic flocks can conflict with this mechanism (Schmidt-Nielsen 1964, 95).

6.2.2. Nutritional value of food

Protein and carbohydrate are the most important nutritional elements of sheep diets (Little & Leslie 1999, 55), where >4% protein intake is necessary for sheep survival (Schaller 1977, 160), and carbohydrate is the greater limiting factor in seasonal resources (Little & Leslie, 1999, 55). Fresh, green grasses are rich in nitrogen and phosphorous essential for protein manufacture (Andrzejewska & Gyllenberg 1980, 204). Grasses lack secondary products which are found in aromatic herbaceous plants that are often toxic or unpalatable to sheep (Hofmann 1989, 448), and do not contain tanniferous phenolic substances found in woody material indigestible to sheep (Landau *et al.* 2000, 41). Compared to taller annual and perennial herbaceous plants, short graze has an extended growing season, and is quick to put on growth after rain (Little & Leslie 1999, 364); thus sheep can maintain constant nutritional levels in all but the driest and coldest parts of the year (Hodgson *et al.* 1991, 222).

For domestic sheep without access to grass-rich pastures there is a range of foodstuffs that, to a greater or lesser extent, meet their nutritional needs. Dried grasses and hay are the most nutritious and have the highest protein content (Capper 1990, 154; Halstead 1998b, 230). Herbaceous species, associated with ruderal field edges and uncultivated fallow, rarely provide nutritionally adequate graze, have a sparse growth habit and a short season (le Houérou 1977, 258). Where weeds are used as fodder, cereal chaff or pasture would be necessary dietary supplements to raise nutrition levels (Halstead 2006, 51; Watson 1979, 104).

Sheep are better adapted than other livestock to crop stubble (Raish 1992, 63). Fresh stubble is nutritious whereas old stubble is only a maintenance food, because the more nutritious

seeds and chaff are eaten first, leaving rough stems which contain less energy and protein (Landau *et al.* 2000, 45). In Iran, the Qashqa'i lambs are put on fresh stubble as it is considered prime food but cannot digest coarse stubble until they are three months old (Beck 1991, 134). Legume by-products (red chaff) are more digestible and have higher energy value than cereal by-products (white chaff), whereas cereals have higher protein content (Capper 1990, 154; Palmer 1998, 160). Legume by-products can maintain lactating ewes, fatten older lambs (Capper 1990, 155), and are used by the Qashqa'i to build condition in rams (Beck 1991, 134).

Nutritional studies are largely confirmed by sheep feeding preferences. Wild herbivores choose to graze on good soils where plant productivity is higher (Sinclair 2000, 250). Bozdağ wild sheep, in central Anatolia, have adapted to steppic plant communities, and on a graze consisting of 400 wild pasture species only eat *c.* 100, selectively choosing fresh green parts and rejecting stalks, twigs or pods (Kaya *et al.* 2004, 231). Domestic sheep, too, selectively chose fresh green leaves from short grasses rather than tussocks (Andrzejewska & Gyllenberg 1980, 204; Grant *et al.* 1985, 992), and herders in the north Levant lop the tops of *Stipa bromus* to encourage this short growth (Hillman 1996, 197). When forbs are still low-growing and green early in the season they are selected by all domestic sheep (Beuls *et al.* 2000a, 220; Grant *et al.* 1985, 992; Papachristou 1997, 88). Overall, even if it means a reduction in consumption out of season, sheep search for short grass or green forbs in preference to browse or taller herbaceous plants (Papachristou 1997, 90). Dedicated forage crops of clover meet both nutrition and preference needs in central Anatolian sheep (N. Kayan, *pers. comm.*, July 2007).

Nevertheless, fresh shoots of young shrubs and trees, such as weeping willow, poplar and *Quercus coccifera*, are occasionally nibbled by domestic sheep in Mediterranean regions (personal observation, 2007; Beuls *et al.* 2000a, 221). Sheep only eat less palatable plants when pasture is stressed, for example Navajo sheep eat aromatic sagebush in high summer

(Bailey 1980), central Anatolian sheep eat thorny *gül otu* in winter (N. Kayan, *pers. comm.*, July 2007), and domestic sheep in Jordan eat tough halophytic grass shoots in autumn (Lancaster & Lancaster 1991, 130). Foddered sheep select grassy hay in preference to leafy hay (Bartolomé *et al.* 1998, 387; Halstead 1998b, 214) and, in the Pindos Mountains of Greece, two sheep escaped from leafy-hay feeding experiments to graze on pasture (Halstead & Tierney 1998, 75). However, after a long period of foddering on dry material, sheep relieve their boredom with green branches of fir (Halstead & Tierney 1998, 72). Sheep find most fallow plants unpalatable, and only eat them when they do not have access to pasture (le Houérou 1977, 258).

Wild sheep are able to survive, but with weight loss, on less nutritious, dry or twiggy herbaceous plants when green pasture is seasonally unavailable, and domestic sheep under severe resource stress will eat fresh and dried leafy fodder from trees (Forbes 1998, 23; Halstead & Tierney 1998, 72). The use of leaf fodder is considered non-productive and indefensible today (Rasmussen 1989, 63), nevertheless the leaves of some trees can be stored up to two years in cool conditions, whereas hay is more likely to rot (Halstead & Tierney 1998, 72).

6.2.3. Location of food resources

Wild sheep move from patch to patch of clean ungrazed pasture, keeping to open spaces and avoiding taller vegetation or woodland (Grellier 2006, 162). In this way they move from lower locations in winter, where late summer dews and autumn rains bring flushes of new growth, towards cooler, wetter upland areas throughout the summer. Domestic sheep, dependent on herding decisions, might be kept in or near the settlement to be intensively foddered or grazed on local resources, or they might be taken out into the wider landscape for extensive grazing, bringing them down to feed on crop stubble when natural resources have dwindled. The extensive strategy more closely echoes that of wild sheep (Bailey 1980, 43; Lancaster & Lancaster 1991, 130) and is far more successful in maintaining high

nutritional levels (Halstead 1996, 23).

Moving herds to pasture is dependent on enough ecological zones to provide wet-season graze and dry-season fodder (Galaty & Johnson 1990; 22). The Lakenkhel liken grazing conditions to a permanent springtime environment as they take their herds uphill from March to June (Balıkcı 1990, 307). During vertical transhumance, the Navajo (Bailey 1980) and the Qashqa'i (Beck 1980; Watson 1979) both pause on lower slopes waiting for snow-melt further uphill in spring, and for stubble availability in summer.

Where herds are kept on local pastures in central Anatolia, sheep are grazed on communal pasture near the settlement in all but the lowest temperatures or deepest snow (N. Kayan & M. Sivaş, *pers. comm.*, July 2007). However repetitive use of dedicated pasture easily leads to degradation, with an increase in animal-resistant plants (Dixon *et al.* 1989). Sheep will not graze in areas sullied by domestic waste, even when abundant in green, pasture plants (N. Kayan, *pers. comm.*, July 2007). On the other hand, proximity to the settlement can provide a variety of fall-back foodstuffs; in the northeast Peloponnese of Greece this includes carob and kitchen waste (Forbes 1998, 22).

6.2.4. Water and mineral requirements

Sheep get most of their water requirements from green vegetation and, in the wild, rarely need to drink. In more arid seasons, pockets of deeper soil and tree-shaded herbaceous growth can provide a landscape mosaic of year-round water and graze availability (Lancaster & Lancaster 1991, 130). All sheep avoid wet areas, where they are at risk of water-borne parasites, miring and drowning, preferring hard, rocky areas to graze (Browman 1990, 334). Bozdağ wild sheep, confined to hills with no natural water sources, dig up *Erodium* tubers for moisture during arid seasons (Kaya *et al.* 2004, 231). Nearby, in Kızılkaya and Kuçukköy, plant water is sufficient until June, after which domestic sheep occasionally eat water-retaining reeds and sedges such as *kova* (N. Kayan & M. Sivaş, *pers. comm.*, July

2007; 2008) but, unlike donkeys, will not eat club-rush (F. Ertuğ-Yaraş, *pers. comm.*, August 2006).

In more arid conditions, wild sheep reduce both their food and water intake (Ryder 1983, 679) but domestic sheep continue to feed and, consequently, need to drink up to 0.7 litres of water per day (Russell 1998, 58). Water intake in domestic sheep varies between breeds, suggesting they have adapted to their climatic conditions, and to the demand on them to maintain high food intake throughout the year (Schmidt-Nielsen 1964, 101).

Sheep need various salts in their diet, but cannot tolerate water with more than 1.3% NaCl concentration; consequently they avoid brackish standing water (Russell 1998, 58). However, in cooler conditions their tolerance rises to 2.5%, making them the most saline-tolerant of the domestic food animals (Schmidt-Nielsen 1964, 103). The Tuareg observe that sheep go blind without salt and consequently need to be pastured on the plains for part of the year (Bernus 1990, 163), and in northern Syria, sheep get their salt needs from backswamps (Moore *et al.* 2000). Magnesium needs in New Zealand breeds are met by high quantities of ingested soil in winter (Field & Purves 1964).

The modelled Çatalhöyük palaeoenvironment (*Figure 5.5*) can now be re-presented in light of the feeding behaviour of sheep, to suggest the distribution of food resources suitable for domestic herds in the surrounding landscape (*Figure 6. 4*). It will be used to model the interpretation of the results from the two datasets used in this research.

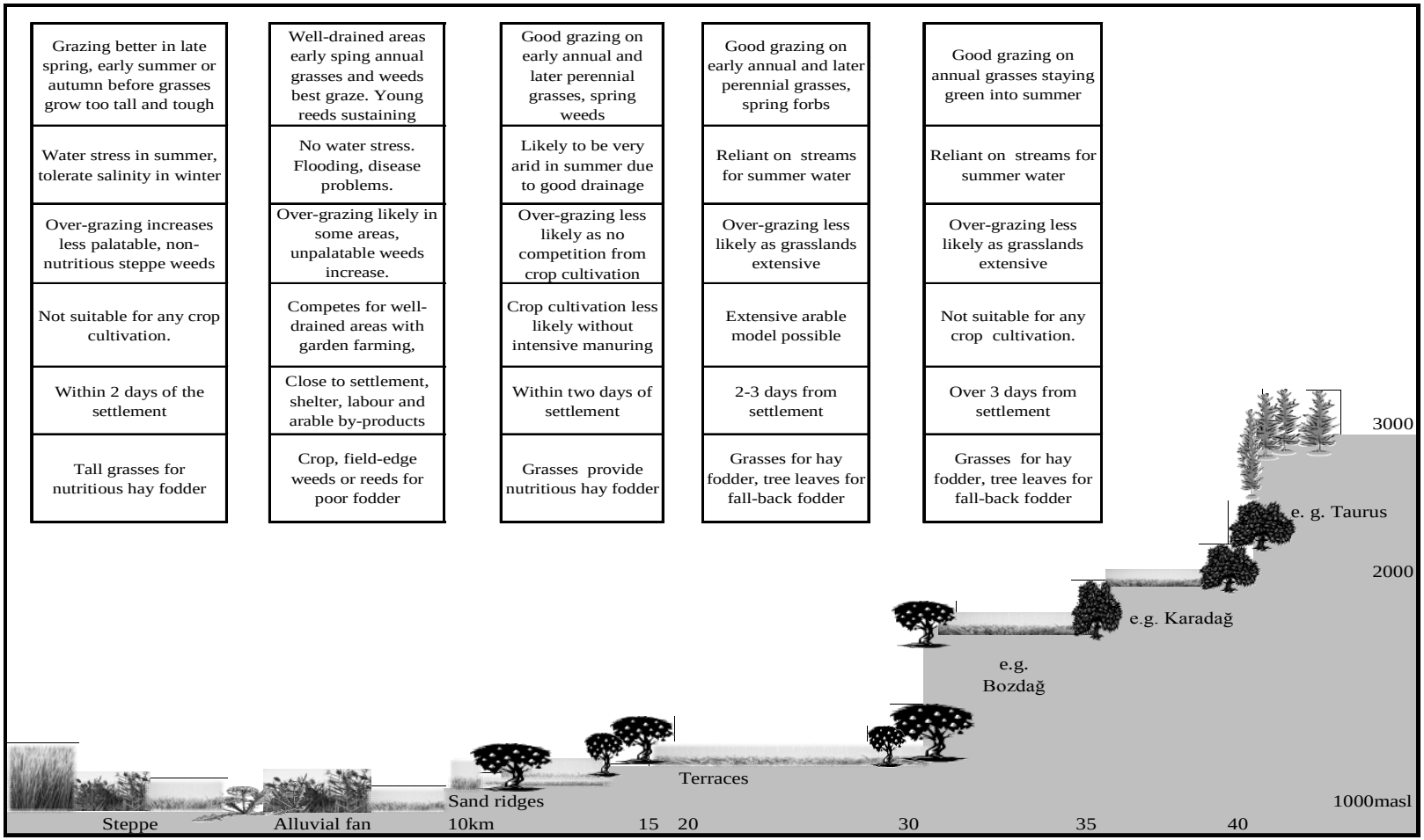


Figure 6.4

Model of Çatalhöyük landscape showing possible distribution of food resources for sheep herds in the Neolithic

6.1. Breeding

Wild and domestic female sheep reach sexual maturity during their second year and continue to breed throughout their nine-year life expectancy (Dahl & Hjort 1976, 90; Kaya & Aksoylar 1992), whereas males mature later and stop breeding earlier (Shackleton & Shank 1984, 506). *Table 6.2* outlines a life history for males and females born in spring; the last row in each refers to the likely longevity in domestic sheep raised primarily for their meat.

Females	March	April	May	June	July	August	September	October	November	December
1st year	Birth →									
				Weaning →						
								Growing →		
2nd	Growing →							First mating		
									Gestation →	
3rd	Parturition →				*Etcetera, until death or the end of useful breeding life*					
Males	March	April	May	June	July	August	September	October	November	December
1st year	Birth →									
				Weaning →						
								Growing →		
2nd	Growing →							Possibly used for mating		
	Or Cull from now onwards possible →									
3rd	*Cull continues possibly*								Most males culled	

Table 6.2
Modelled life histories of male and female sheep born in 3 months of spring, and raised in domestic herds primarily for their meat products

Mature females come into oestrus every 15–19 days although they are only fertile under certain conditions (Dahl & Hjort 1976, 90); their fertility is increased in the proximity of rams in rut (Schaller 1977, 256). Peak fertility has variously been attributed to temperature (Schaller 1977, 124), condition (Lancaster & Lancaster 1991, 129) and daylight length (Rosa & Bryant 2003; Zarazaga *et al.* 2005). Daylight length is now the accepted trigger, although it serves to synchronise fertility rather than control it completely (Rosa & Bryant 2003).

Daylight length possibly operates indirectly by altering seasonal plant productivity and thus the condition of the sheep; certainly, alterations in the seasonality of peak fertility have been empirically related to the manipulation of nutrition levels (Zarazaga *et al.* 2005). In addition, wild sheep from similar latitudes, with the same daylight lengths, mate at different times in association with the local availability of resources (*Table 6.3*). The mating period of many domestic breeds has been advanced, delayed or re-scheduled to other seasons, effected by manipulating the condition of the females through nutritious food supplements (Halstead 1998a, 8; Landau 2000, 47). The Basseri allow breeding three times a year to meet their various product commitments, arguing that, as their sheep are reared extensively, they are able to maintain condition throughout a long season of good resources (Barth 1961). In second millennium BC Babylon, sheep were mated in August (Lancaster & Lancaster 1991, 129) and in Roman Sagalassos (west Turkey) sheep were mated in early summer (Beuls *et al.* 2000a).

Wild sheep	*Area*	*Mating season*	*Reference*
Bozdağ	Central Anatolia	December	Kaya & Aksoylar 1992
Mouflon	Corsica	Mid-October to end November	Schaller 1977, 364
Marco Polo	Pamir Mountains	December to early January	
Bighorn	USA	Late November to December	

Table 6.3
Mating seasons of wild sheep from Northern hemisphere mid-latitudes

The gestation period is *c.*150 days in all sheep and, in southwest Asia, where conception is most common in early autumn and less so in spring, ewes tend to breed once a year but might breed every 18 months (Dahl & Hjort 1976, 91). Larger mammals with long gestation periods cannot vary their mating time in anticipation of optimum conditions at birth (Lenarz 1979, 675), nevertheless the timing of the breeding season generally results in a birth season where the last two months of maximum foetal growth and the first two months after parturition coincide with the most nutritious food availability and the most benign seasonal climate (Lancaster & Lancaster 1991, 129). Bozdağ wild ewes, raised on high mountain slopes, give birth in late May coinciding with the first spring plant growth (Kaya & Aksoylar 1992, 237). In arid areas with a potentially long plant-growing season but with unpredictable rains to effect germination, good lambing conditions might occur at any time over a long period; wild bighorn desert sheep in Mexico have a broad mating season from June to December, facilitated by a longer period of fertility and by rams staying with family herds for the greater part of the year (Lenarz 1979, 675).

During rutting and conception, domestic ewes and rams are often put on the best pasture or new stubble with easy water access, or given high quality hay and arable by-product fodder. Food quality is then unimportant until two months before parturition. At parturition it is common for wild ewes to withdraw to more isolated and rugged territory and to remain there until a few days after giving birth (Schaller 1977, 277). In the following few weeks, suckling Bozdağ ewes seek the protection of low, sheltered valleys (Kaya *et al.* 2004, 230), domestic lambs might be hand-reared (Bailey 1980) and kept in tents or byres (Edelberg 1966/77, 384; Hole 1978, 151). However newborns can easily be suffocated or succumb to disease in confined spaces (Beck 1991, 133).

New-born lambs are vulnerable to climate extremes, cannot control their body temperatures and, in cold spells, fail to thrive (Halstead 1998b, 214; Schaller 1977, 129); lamb mortality is

commonly as high as 30–40% (Dahl & Hjort 1976, 91). The yearning rate measures the average number of lambs born per year, and despite less nutritious steppe vegetation, Bozdağ wild sheep achieve a 1.0 rate (Kaya &Aksoylar 1992, 237). The yearning rate for domestic sheep in mid-latitudes is 0.8 on unimproved pasture rising to 1.5 on improved pasture (Dahl & Hjort 1976, 91; Russell 1988, 62).

Wild mouflon lambs start eating grass by five days, and urials (*O. vignei*) by seven days (Schaller 1977, 282); weaning is complete by four to five months with the bond completely severed by the birth of the next lamb (Geist 1971; Schaller 1977, 283). Domestic lambs, in central Anatolia, start eating tender, fresh grass by the end of their first week (N. Kayan & M. Sivaş, *pers. comm.*, July 2007). Both lambs and ewes need good pasturing and watering conditions in the first two or three months of suckling, straw fodder is not enough for Qashqa'i sheep (Beck 1991, 133). After weaning, drying off occurs naturally in wild ewes as they are in poor condition, and it is encouraged in domestic ewes by putting them on poor graze for a while (Ryder 1983, 12). Domestic herds, raised for milk products, usually have a shortened weaning time, although this is not conducive to weight gain in beef herds (Balasse & Tressett 2002, 858).

6.2. Body temperature regulation

The thick, hairy fleeces of wild sheep include a more substantial, woolly under-kemp than in modern domesticates, and are efficient in temperature insulation and water repulsion (Russell 1998, 56). Consequently, sheep maintain remarkable thermostability although large temperature changes are stressful (Silanikove 2000, 10). In arid conditions sheep lose extra body heat through panting and secondary sweating, enabling them to manage a diurnal temperature variation of 1.5–2.0 °C (Schmidt-Nielsen 1964, 95). Seasonal moulting is advantageous where ambient temperatures remain below body temperatures but in hot, arid environments retaining wool as an insulator is advantageous (Schmidt-Nielsen 1964, 97).

All sheep actively seek breezes and shade, preferring terrain where there are shaded gullies or rocky overhangs, and flocking together and orientating themselves to minimise the effective body area for heat exchange (Silanikove 2000, 9). In high temperatures, Turan domestic sheep adapt their diurnal activity, moving and grazing in cooler parts of the day or by moonlight (Nyerges 1980, 39).

6.3. Defence mechanisms, disease and death

All sheep use safety in numbers as their guard against predators such as raptors and carnivores and, at the first sign of danger, will flee together. In this situation domestic sheep ignore calls and run blindly with no homing sense; this strategy can lead to accidents in mountainous topography (Dahl & Hjort 1976, Russell 1988); extensive herding on open hillslopes allows greater visibility so that large herds can easily be guarded (Halstead 1996).

Sheep have been observed to be more adept on pastures and paths they have previously used, for example, choosing the time of day to tackle difficult places when the sun is neither in their eyes nor casting confusing shadows; good herders will schedule herd movement with this in mind (Grellier 2006. 164). Learnt behaviour includes recognising human activity, for example, experienced transhumant sheep in Languedoc manoeuvre to set off when the transhumance bell is rung, whereas sheep raised in nearby villages ignore the bell (Grellier 2006, 162).

Diseases and parasites that lead to death include foot and mouth, scabies and rinderpest, and round worms and ticks are debilitating; all are more prevalent in over-stocked, stressed pastures (Ryder 1983; 778). Liver flukes live in marshy areas or in long, wet pasture and can kill sheep, and foot-rot is a debilitating condition associated with marsh conditions, pastures where recovery time has not been scheduled and stable bedding (Ryder 1983; 778). At all

stages in the sheep's life, poor condition brought on by inadequate diet or harsh temperature extremes reduces the rate of recovery from illness or accident (Dahl & Hjort 1976; 236). The fat content around the muscle and in the bone marrow is almost completely depleted in rams during and after rut, and in ewes during birth and suckling, leaving no energy reserves (Speth & Spielmann 1983, 9). Luristani herds are expected to be decimated every few years, but rebuild quickly as herds can commonly increase 6.3% annually, rising to 19.5% in favourable conditions (Hole 1978, 142; Redding 1981).

In domestic herds, male sheep are usually slaughtered before senescence, firstly to remove less valuable animals from resource competition with the breeding stock, and secondly, in meat herds, to use their meat, bone and hide products. Fat provides energy, is easily stored, and is often a more important ingredient in everyday consumption than protein-rich lean meat, which on its own is dangerous for humans (Speth & Spielmann 1983, 9). Elderly ewes are fattened for slaughter by Yomut Turkmen (Dahl & Hjort 1976, 94), and are considered to give the best fatty meat in Anatolia (Payne 1972).

Meat herds destined for slaughter are often fattened up on good pasture near the settlement for slaughtering convenience, and slaughtered, ideally, when the sheep provides the best returns for the least outlay (*Table 6.2*). Early autumn is considered the best time to slaughter sheep as the condition lost during rutting and lambing is largely replaced, and as the amount of stabling and foddering needed during the following winter is reduced. If spring lambs are to be killed, then autumn slaughter is timely before they reach fertile maturity (Dahl & Hjort 1976, 207).

6.4. Herd size and composition

In both wild and feral herds, rams stay with females for a while after mating but do not maintain a harem and, once oestrus and rutting has passed, usually separate into male and

family herds that show remarkable social stability over years (Shackleton & Shank 1984, 506). Seasonal herd splitting reduces male aggression and serves to spread pasture exploitation over a wider area (Russell 1988, 77). Wild and feral herd sizes vary with environmental openness (Shackleton & Shank 1984, 502). Sheep are gregarious animals that group together when eating as part of herd socialization; they eat more and thrive better in larger herds and have been observed to be unhappy in small groups, trying to flock together if separated (Dahl & Hjort 1976, 255).

In domestic herds, it is common to separate breeding rams and ewes except when breeding is desired (Dahl & Hjort 1976, 264). Male and female lambs need to be separated before six months when they become fertile and aggressive (Ryder 1983, 12). Male and females can be herded together if castrated; the Masai and Tuareg hobble their rams, or tie and cover the ram penises (Cranstone 1969).

As a risk-management strategy, breeding herds may also be split temporally; climatic variability is such that the Tuareg run two herds with different breeding cycles on different pastures (Cranstone 1969, 254). In Provence, southern France, some lambs are fattened for autumn slaughter and others kept back until spring (Ginstburger *et al.* 1990, 187).

Domestic herds may be split and distributed to different parts of the landscape in response to seasonal graze or fodder availability; resource conservation plays a large part in deciding strategies. The Basseri split their herds further as summer progresses to conserve diminishing resources (Barth 1959/60, 5; Squires 1975, 44). The Bedouin and Fellahin of eastern Jordan manage resources flexibly, where the Bedouin might sometimes split their herds into small groups to graze close to the settlement, and the Fellahin might amalgamate small herds and take them out to graze over wider areas (Lancaster & Lancaster 1991, 136).

Herd splitting can target resources to certain herd sections. During the weaning period in meat herds, Turkana fallow herds (juveniles growing to maturity and barren females) are moved to more distant pastures whilst ewes and lambs are kept longer on better pastures (Little & Leslie 1999, 78). If extensive practices demand seasonal movement of herds, splitting often reflects the different speeds at which lactating ewes and lambs can move through the landscape (Little & Leslie 1999, 78). Where meat and fat are the product goals, animals due for slaughter might be fattened on better pastures and moved to a slaughtering location more convenient to the consumer (Dahl & Hjort 1976, 264).

Domestic herd size bears little resemblance to wild herds, and indicates the degree to which environmental awareness has been suppressed. Herd numbers and proportions of male, female and young sheep must be large enough to maintain herd security whilst meeting the needs of their consumers (Redding 1981). Meat herds are relatively easy to maintain, with nutritional needs that can be met from seasonal resources, and herd security is less at risk when ewes are not milked (Halstead 1989, 73). Herd size includes an element of surplus production, produced as a normal response to variability (Halstead 1989), and best achieved by constantly aiming to increase herd size (Dahl & Hjort 1976, 270).

Herd size and composition reflects the society's product goals, and the balance between specialisation and subsistence (Halstead 1998b). In Luristan meat herds, 1000 sheep are considered necessary to provide meat for 20 people for one year (Hole 1978, 146). Larger herds may be maintained by using extensive herding practices, and are considered necessary to meet the scale of specialisation required for specialised secondary product economies (Halstead 1996).

Herd size also reflects the ease of herding. On lightly wooded, open Iranian hillsides Watson (1979) records herd sizes of 150–200 managed by one person. In central Anatolian mixed agricultural villages, herd sizes can reach 80 on degraded open fields (M. Sıvaş & M.

Tokyağsun, *pers. comm.,* July 1995; July 2007) and 575 in fertile, well-watered valleys (N. Kayan, *pers. comm.,* August 2007). Sheep grazed around field edges are restricted to small groups of 15 as poor visibility reduces herding effectiveness and as it is vital to prevent them straying onto crops (M. Sıvaş & N. Kayan *pers. comm.,* July & August 2007).

6.5. Movement

The ethology of sheep movement is closely related to their feeding, breeding and defence mechanisms, and has been addressed in previous sections. This section focuses on herd movement decisions taken by herders.

Modern sheep breeds thrive in a range of conditions, where some are better suited to staying in one place and others need more constant temperatures and graze made possible by seasonal movement. Basseri sheep are extensively reared and considered large and productive, however attempts to settle them result in their death, as they are not adapted to extremes of weather or unpalatable dry food (Barth 1961, 6).

As sheep graze they comfortably cover 10km a day over quite steep and rocky ground (Russell 1978, 59). In arid seasons, water becomes the limiting factor, restricting Bozdağ wild sheep to within a three-day journey, 30–35km from a water source (Dahl & Hjort 1976, 249; Kaya *et al.* 2004, 231). When sheep are droved to new pastures in east Jordan, they can cover 16–20km a day, feeding on the hoof (Lancaster & Lancaster 1991, 130), but move more slowly on longer journeys (Russell 1988, 76). Small Lakenkhel herds move too quickly to graze properly, whereas large herds are too slow, leaving only trampled graze for sheep taking up the rear (Balıkcı 1990, 310). Herders have to balance speed against maintaining condition in the sheep; sheep in the Balkans can lose 10–15% body weight and take two to three months to recover when droved 100km in three to four days, but suffer little weight loss when taking two to three months (Nandris 1990, 102).

Herd movement decisions are influenced by factors that might cause adjustments to the optimal scheduling and location of herd pasturing. Of these, the protection of young arable crops in spring, and the timing of harvest in late summer are perhaps the most important. In central Anatolia, locally grazed fallow herds are put on field edges and local pasture in winter returning to village byres each night, but in summer they are moved further to dedicated pasture areas, and later onto stubble, only occasionally spending time in village-edge sheepfolds (N. Kayan & M. Sivaş, *pers. comm.*, July 2007).

More extensive herd movement away from villages is scheduled to coincide with the arable season as well as seasonal pasture availability. Birthing is usually carefully co-ordinated so that lambs are able to make the journey, but where climate variability disrupts timing, Turan lambs are born during transhumance rather than delay moving herds from arable fields or reaching natural food sources (Nyerges 1980, 36) (*Figure 6.5*).

Figure 6.5
Newborn lamb carried during transhumance in Turan
Nyerges 1980, 36

Herd movement has to be scheduled so that suitable herders are available, and freed from other tasks (Forbes 1998, 24). The status of the herders can ease or delay access to optimal pasturing; the Basseri have a complex hierarchy of finely timed vertical movement in the landscape, where large herds take most of the pasture in high season, whilst poorer herders wait to bring through their smaller flocks on pasture past its peak (Barth 1959–60).

In some areas, such as hunting grounds or sacred places, herd movement may be proscribed, and in others may be encouraged to facilitate collection of other environment resources; the Qashqa'i make detours for fruit, fuel and fodder (Beck 1980, 337; Salzman 2002, 248). In the Taurus Mountains, the seasonal prevalence of pests and diseases in village houses encourages an early move to mountain pastures (herder's daughter, *pers. comm.,* June 1999).

6.6. Çatalhöyük herders

Çatalhöyük was a large settlement (Cessford 2005b), where the zooarchaeological evidence suggests that 'everyday' consumption of sheep meat and fat was the prime goal (Russell & Martin 2005). The yearly schedule can more easily be established for everyday consumption than for feasting and ritual, and would have been dictated largely by the seasonality and distribution of resources, the breeding pattern, and the settlement's product demands. Some herd splitting probably would have been desirable and necessary at Çatalhöyük, in order to manage breeding and slaughter, and to target food and labour resources. Zooarchaeological evidence has not established the birth season of Çatalhöyük sheep, although ethological reasoning makes spring the most likely. Mortality profiles suggest that some early slaughter could have been 18 months later, possibly in autumn (Russell & Martin 2005) (*Table 6.2*).

The palaeoenvironment, including the cultivated areas, potentially offered Çatalhöyük herders a choice of sheep herding strategies (*Figure 6.4*). Scheduling the best resource provision for herds might have been met by emulating wild sheep ethology, following fresh grassland pastures into the hills during spring and summer and returning to more sheltered pastures on the Çarşamba fan and plain in autumn and winter; carbon stable isotopic evidence offers some support for this strategy (Richards *et al.* 2003). If the arable and pastoral economy were integrated at Çatalhöyük, herds might have had access to stubble in late summer and crop by-products for foddering in the winter, as is widely practiced throughout semi-arid lands today (Dixon *et al.* 1989).

Such an extensive schedule has labour costs that would have taken sections of the household or community away from the settlement for large parts of the year. The Fulbe consider that once a herd is more than one day's travel away, direct and continuous communication is broken, and the herder becomes more independent in decision making (Grayzel 1990, 49). Herders are usually men; though the Masai put girls in charge of caprine herds (Galaty & Johnson 1990, 24); there is no direct evidence that men were the herders at Çatalhöyük (Molleson *et al.* 2005). Their work could have been helped by domestic dogs and goats, both present in the Çatalhöyük assemblage (Rusell & Martin 2005); dogs are highly effective guards (N. Kayan & M. Sivaş, *pers. comm.*, July 2007), although less so in heavily wooded landscapes (Grellier 2006); goats act as leaders and are stabilising influences (Nyerges 1980; 37).

Under an extensive herding system, herders would have needed provisions brought to them, possibly by family members remaining in the settlement (Grellier 2006). It is possible that whole family groups might have moved to summer pastures, living in more temporary shelters (Moreno & Raggio 1990; *pers.obs.*, Taurus Mountains, August 1998). Satellite camps are rarely visible archaeologically (Kramer 1982), but Pinarbasi B, at the foot of Karadağ, is thought to be a possible satellite camp for Çatalhöyük (Baird 2005; Carruthers 2003). Camps can themselves be centres for further satellite camps (Sperling & Galaty 1990; 81). In the Balkans, families divide up seasonally, all coming together again for the autumn harvest (Nandris 1990), and the return from distant pasture is a high point of the social year for the Fulbe (Grayzel 1990, 52).

As a second possibility, Çatalhöyük herders might have used an intensive herding strategy, where herds remained near the settlement year-round, supplementing any pasture shortages arising from unsuitably damp conditions on the Çarşamba fan with grazing on field-edge weeds and stubble and with fodder. Different labour costs are incurred by a more intensive

strategy but proximity to the settlement might ease co-operative scheduling (Raish 1992, 58). Qashqa'i infants practise herding on young lambs, older children take lambs onto field-edge forage, and ten-year-old boys manage herds of 100 (Beck 1980, 333). In Kuçukköy and Kızılkya households often combine herd parts with shared goals (N. Kayan & M. Sıvaş, *pers. comm.*, July 2007). At Çatalhöyük, evidence of weed seeds in dung (Fairbairn *et al.* 2002) might indicate these grazing practices, but could also indicate fodder provision.

As a further possible herding strategy, Çatalhöyük herding might have been relatively close by within a few hours walk, in 'outfields' (the Roman concept of '*saltus*') on the margins of cultivated land (Boyazoğlu & Flamant 1990, 377; Raish 1992, 58); these might have included nearby sand-ridges or areas of the plain where nutritious wild grass pastures were likely to have grown. Herd movement up to five kilometres away emulates that seen in wild goats and serves to space animals out thinly enough to preserve the ecological equilibrium of Mediterranean pastures (Schaller 1977). It is the system practiced today in the nearby village of Küçükköy.

Other herding tasks might have included slaughtering, building sheepfolds and shelters and collecting fodder (Sperling & Galaty 1990; 83). Zooarchaeological body-part evidence suggests slaughtering took place near the settlement (Russell & Martin 2005), and microstratigraphical evidence of penning areas and deposits indicate some settlement-edge stabling (Matthews 2005). Fodder collection brings would have brought its own scheduling costs. Hay, the most nutritious fodder, is harvested when there are few other demands on labour, but its production is susceptible to drought and rain (Halstead 1998b, 215). Leafy browse, even though only a fall-back option, is more easily stored, but its prime collection time coincides with late harvesting and crop processing and would create labour scheduling problems (Halstead 1998b, 224). Phytolith analysis of Çatalhöyük caprine dung shows that dicotyledonous material has been eaten, but cannot differentiate between sheep and goats, nor weeds and tree leaves (Ryan 2010).

As there is little evidence of specialisation at Çatalhöyük, other tasks, including arable farming, would have needed scheduling. The Jordanian Bedouin used to move between their fields and their upland herds (Betts 2001, 615), and Lakenkhel herding is seen as a partial activity, needing the co-operation of at least two skilled adults, typically brothers, one herding and the other farming (Balıkcı 1990; 309).

In the optimum Neolithic environment there would have been the potential for building large herds quite rapidly at Catalhoyuk. Surplus herds have been likened to walking larders, storing energy and protein from graze and any arable excess, as meat and fat (Halstead 1989). Surplus can be used to manage risk, be absorbed by feasting or gift exchange or by setting up small founder flocks in new communities or households (Halstead 1989). Herd size may also be a symbol of the wealth and status of a community, a household or an individual, although this might not be possible where the products are the economic mainstay (Cranstone 1969, 249). The foundation of Navajo society rests on its livestock, where as a co-operative enterprise, it serves as a symbol of social integration and kinship solidarity (Bailey 1980). However, there is only minimal evidence of herding carrying any status at Çatalhöyük (Russell & Düring 2006).

6.7. Summary

The ethology of sheep and the ethnography of herding provide, in tandem, evidence of, and insights into successful herding practice. Where the landscape opportunities for herd and resource management can be modelled, as in *Figure 6.4*, it is possible to predict some of the spatial and seasonal perameters of successful herding.

Table 6.4 builds three models that might be relevant to sheep herding in the Neolithic of Çatalhöyük. The first table (*Table 6.4A*) summarises the breeding cycle of Bozdağ wild

sheep and shows how the seasonality of their breeding and movement is synchronised with resource availability and need. In *Table 6.4B*, the schedule for domestic sheep herds in the nearby village of Küçükköy is presented. As these sheep give birth earlier in the year than wild sheep, and as their movement is more confined by milking and labour scheduling, adjustments have to be made to the seasonal food resource allocation for breeding herds in particular; these are reliant on arable stubble and by-product fodder. *Table 6.4C* presents one possible model of the annual requirements of a sheep herd raised primarily for meat products, such as is suggested for Çatalhöyük herds. The model assumes an earlier birth season, as with the Küçükköy herds, but a more benign Neolithic winter where grass growth and seasonal temperatures do not restrict sheep to byres to the same extent. The restrictions imposed by milking are removed so that, by two months after birth, ewes and lambs can be run as fallow herds on less optimum graze and needing less attention.

This chapter is the last in a series of five chapters that consider the bodies of knowledge that Çatalhöyük herders might have brought to bear on the management of sheep and their food resources. Each chapter contributes to an interpretation of possible herding practices at Çatalhöyük and to predictive models of the seasonal use of the palaeoenvironment under different herding regimes. The following three chapters introduce the methodologies selected for this research and model how their highly contextual data might provide evidence on the birth season, movement and foddering of individual sheep.

	Mar	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*
Breed -ing	Late gestation period		Birth	Early lamb growth and suckling		Later lamb growth, less suckling and weaning	X years pass	Rutting		Mating	Early gestation period	
Feed -ing	Spring grass		Young grass			Dry grass, least food		Autumn grass re-growth		Winter grass, less food		
Move -ment	Family herds in sheltered parts of lower slopes, male herds further uphill			Movement of all herd parts further uphill to cooler locations		Remain uphill		All herd parts return turn to lower locations and form one group			Herds split again but stay in lower more sheltered locations	
Cond -ition	In ewes, good condition necessary for foetal growth, milk production In lambs good condition necessary to survive poor weather					Condition at its poorest, encouraging weaning. Less food prevents over-heating		Ewes and rams need to be in good condition for rutting and maximum fertility			Condition poor, but maintained by spells of grass re-growth	
A. Bozdağ wild sheep												

Breed -ing	Birth	Early lamb growth and suckling	Later lamb growth, less suckling and weaning	Rutting, mating condition	Mating	Early gestation period	Late gestation period
Breeding herds	Restricted to field edges near village for ease of milking, but need food supplements until nutritious crop stubble available. Water to offset over-eating and -heating		X years pass	Nutritious fodder needed, crop stubble less nutritious. More water to offset over-eating and -heating	Put onto dedicated pastures	Night in byres. Good weather on field edge graze	Nutritious fodder needed for ewes
Fallow herds	Moved away from growing crops onto dedicated pastures or fallow fields	No uphill movement, young grass withers earlier, fallow weeds finished, crop stubble later.		Remain on crop stubble and dedicated pastures		In byres at night, in good weather grazed on field edge weeds	
B. Modern Küçükköy sheep bred for milk products							

Breed -ing	Birth	Early lamb growth and suckling	Later lamb growth, less suckling and weaning	Rutting, mating condition	Mating	Early gestation period	Late gestation period
Breeding herds	Early field-edge weeds might be convenient to protect lambing closely. If so, nutritious fodder supplement needed		Could be moved to pasture. If no uphill movement, young grass withers early, field-edge weeds finished, crop stubble later. Poor condition begins early	X years pass Nutritious fodder needed, crop stubble less nutritious. Water to offset over-eating and -heating	After mating could be returned to pastures with autumn grass re-growth		In byres or folds when cold, nutritious fodder needed for ewes
Fallow herds	Could be moved away from growing crops onto good spring pasture			Graze on poor crop stubble or pasture. Poor condition continues	Autumn re-growth grass on pasture		In byres or folds when cold, or deep snow. In good weather grazed on poor pasture
C. Modelled domestic sheep herd bred primarily for meat and born in early spring							

Table 6.4
Three models of herd resource requirements associated with the breeding cycle, product goals and labour demands

7. OXYGEN ISOTOPE METHODOLOGY

7.1. Introduction

> Stable … isotope analysis is one of the very few methods capable of identifying events within the lives of individuals, and also for identifying dietary and life history differences between individuals, in addition to the opportunities for broader scale inter-group and even inter-species comparisons. Thus the approach can operate at many scales.
>
> (Lee-Thorp 2008, 944)

The use of stable isotopes in this research is based on the principle that 'you are what you eat' – that is, the tissues in an animal's body are derived from its dietary intake (Hedges *et al.* 2008, 115). Closely related wild and domesticated taxa have broadly similar dietary preferences, but they occupy different ecological niches and habitats as a result of domestication. These 'domestic habitats' may be associated with relatively subtle environmental differences which may leave their traces in isotopic signatures (Lynch *et al.* 2008, 1025). Knowledge of such differences can contribute to an understanding of early domestication practices.

Stable isotopes have the advantage of directly relating an animal to its environment, with a time resolution consonant with the rhythms of a herd animal's life and of its herding schedule (Tornero & Saña i Seguí 2008). Stable isotope analysis offers archaeologists the opportunity to move from generalised arguments about herding strategies to considering the specific forms they may have taken. As an example, stable isotope analysis of 'Ain Ghazal caprine herds might offer evidence that supports either the model of nomadic caprine pastoralism proposed by Köhler-Rollefson (1989; 1992) and Rollefson and Köhler-Rollefson

(1993), or the model of selective integration of domestic resources by hunter-gatherers proposed by Byrd (1992).

There are many elements which exist in different stable isotopic forms with different numbers of neutrons and thus with different atomic mass. These stable isotopes exist in fixed proportions on earth, but in different environments the proportions of these isotopes might vary, thereby altering the isotopic ratio. The use of stable isotopes depends on understanding the processes that cause these variations and identifying the isotopic ratios associated with different environments. However, stable isotopes are only one among several sources of evidence. As such, they can inform our reconstructions of the past to a considerable extent, but they cannot be a substitute for the archaeological groundwork and the careful and balanced appraisal of as many kinds of information as possible (Bickle & Hofmann 2007, 130).

Oxygen stable isotopes in sheep tooth enamel are used in this research because they offer direct evidence of seasonality and locality; they are a tool for investigating the scheduling of mating and lambing, the exposure of herds to seasonal climate extremes, and movement between different food resources. Oxygen isotopes have the potential to discriminate the seasonality of herd management, reflecting underlying management decisions where herd security and food resource availability would be weighed against societal demands for easily accessible animal products and labour scheduling costs. Such decisions might indicate, for example, the manner and the extent to which herders and arable farmers co-operated over pasture-land and fodder provision. Other stable isotopes – specifically of strontium, carbon and nitrogen – have been discussed in *Chapter 1*.

7.2. Previous archaeological applications of oxygen isotope analysis

Oxygen isotope analysis of archaeological biological remains has been used in a variety of applications. In humans, comparison of signatures from tooth enamel and bone are often used as evidence of birthplace and subsequent long-distance movement. The use of oxygen isotopes alone, taken from frozen remains of a Neolithic man, has provided evidence of altitude, latitude and watershed in the Alps in order to establish where he originated (Muller *et al.* 2003). In combination, oxygen and strontium stable isotope signatures can provide evidence of an environment's hydrology and geology, respectively. Archaeologists have applied this to questions of migration and matrilocality (Bentley *et al.* 2005). Where the signatures in human tissue are compared to those in small mammals (e.g. rabbits) living in the site locality, a more robust local signature may be modelled (Bentley & Knipper 2005). Caribou migration patterns were explored with chronological sequences of strontium and oxygen data in tooth enamel; non-seasonal oxygen signals were associated with migration across climate zones (Britton *et al.* 2009).

Variation in oxygen isotope signatures in tooth enamel has also been used to investigate palaeoenvironments. At a coarse timescale, oxygen isotope data from *Bos indicus* specimens from different cultural levels were used to identify climate change (Sharma *et al.* 2004). At higher resolution, differences in mean oxygen isotopic values in bovid tooth enamel indicate inter-annual variation, suggesting that an attritional death assemblage had accumulated over years, rather than resulting from one catastrophic event (Zazzo *et al.* 2002).

The archaeological application of oxygen isotope analysis in establishing the seasonality of food intake and movement of animals has particular relevance for this thesis; however, its use has most commonly been in combination with analyses of carbon, nitrogen or strontium isotopes. Balasse and her colleagues (all references) have pioneered the use of oxygen

isotopes in investigating past herding practices. Their work provides the basis for the use of oxygen isotopes in this research.

The combined use of oxygen, carbon and strontium isotopes in the tooth enamel of a range of domestic herd animals has contributed to questions on Late Stone Age herd movements in Kasteelberg, southern Africa (Balasse *et al.* 2002). Oxygen isotope signatures established the seasonality of the strontium signatures (here differentiating between upland and coastal locations), and carbon signatures (associated with C3 and C4 plant ingestion). Thus the authors were able to show that, in some herds, changes in food intake were related to annual transhumance rather than to seasonal vegetation changes. The same oxygen isotope signatures were used to investigate the breeding season of sheep at the same site (Balasse *et al.* 2003). It was found that herders had a twice-yearly breeding programme, following the natural breeding pattern of sheep native to these latitudes. This indicates that there was a risk mitigation strategy in place, where limited seasonal food resources were spread over two breeding seasons. In addition, the oxygen isotope signatures were used to show that this pattern did not result from sheep having been brought in from a region where a different climate-induced birth pattern was in place.

Balasse and Tresset (2007) investigated the manipulation of the breeding season using oxygen isotope analysis of sequential signatures in tooth enamel; the first stage of a larger project focused on two Neolithic sites in the Orkneys. Early in the settlement of Knap of Howar, sheep had a tight breeding season relatively early in the year, whereas later the breeding season was more extended and more closely resembled the late spring birthing pattern seen in modern sheep. A larger project arising from this work is planned and hopes to disentangle whether the patterning was climate-induced or the result of human intervention (Balasse & Tresset 2007).

Oxygen isotope analysis has been applied to archaeological questions in the Neolithic of

southwest Asia. A combination of carbon and oxygen isotope data from *Bos* sp. from Tell Halula, Syria, was used to differentiate between herding systems and hunting practices between 7800–7000 cal. BC (Tornero & Saña i Seguí 2008). The precise timing of the transition from a more temperate to an arid climate in the Levant – possibly the cause of changing herding practices at ‘Ain Ghazal – was investigated with data from a chronological sequence of specimens (Wiedemann *et al.* 1999). On preliminary analysis, the authors proposed that a temporal resolution of five weeks is possible in cattle teeth.

Bocherens *et al.* (2001) and Mashkour *et al.* (2002) used oxygen isotope signatures from modern transhumant and non-transhumant herds in order to model prehistoric herd management in 6th–5th millennium cal. BC sites on the Qasvin Plain, northwest Iran. The authors support their model with seasonal meteoric water isotope signatures at different altitudes, arguing that a combination of upland and lowland signatures would result from transhumance during the period of enamel formation. A small study found that caprines might have been moved to higher altitudes for part of the year (Mashkour *et al. 2002*, 122).

At Nevalı Çori, in eastern Anatolia, Lösch *et al.* (2005) used a range of isotopes in bone tissue to investigate human and domestic caprine diet. The oxygen isotope signatures in humans were, with one exception, tightly clustered, suggesting that there was little immigration into the settlement. Also, the signatures in a range of wild animals were consistent with both the known altitudinal range of their habitats and with known altitude-induced variation in oxygen isotope values.

The examples show a variety of ways in which oxygen isotope analysis has been applied to archaeological questions. Each example discusses methodological limitations, and many have been supported by methodological research. This chapter continues with a description of the behaviour of oxygen isotopes in the environment, in animal tissues and in archaeological samples; within this context, methodological limitations will be discussed.

7.3. Oxygen isotopes in oceanic and meteoric water

Oxygen has two main stable isotopes, ^{16}O and ^{18}O. Their abundance on earth is fixed at approximately 99.8% ^{16}O and 0.2% ^{18}O (Schoeninger 1995). The international standard VSMOW (Vienna Standard Mean Oceanic Water) was established from the isotopic ratio ($^{18}O/^{16}O = \Delta^{18}O$) in a particular sample of oceanic water. The ratios in all other samples are reported as relative differences ($\delta^{18}O$) with the standard, and measured in units per mil (‰). $\delta = (R_{sample}/R_{standard}) - 1.10^3$, where R is the measured ratio of the sample (Leng 2006, xi). The difference might be greater or less than the standard and $\delta^{18}O$ values are said to be enriched or depleted in comparison.

Oxygen isotopes differ significantly in their mass, such that the molecules that contain them have a markedly different rate of transfer within chemical reactions and from one phase to another. Molecule transfer from a liquid to a gaseous phase is more readily achieved by those containing the lighter isotope, ^{16}O, whereas molecules containing the heavier isotope, ^{18}O, more readily transfer from gaseous to liquid phases. This difference in behaviour alters the original ^{16}O to ^{18}O ratio, so that the source material $\delta^{18}O$ differs from the transferred fraction, this process being termed fractionation. When interpreting the isotopic signatures in any specimen it is necessary to understand the environmental conditions of each fractionation that contributes to the final signature.

The first factor that contributes to an isotopic signature is the source of the oxygen, which in animal and plant tissue is predominantly water, and ultimately oceanic water. Within the global hydrology cycle, 90% of water exchange with the atmosphere takes place over oceanic water (Dansgaard 1964). Oxygen isotopes are in equilibrium in oceanic water but, during water exchange at the surface, molecules containing the lighter oxygen isotope are preferentially taken up in the vapour stages of cloud formation, whilst water molecules with the heavier oxygen isotopes tend to remain behind in the oceanic water (Gat 1996). The

oxygen isotopic composition of the atmospheric moisture is thus depleted in the heavier ^{18}O isotope.

The rate of exchange is a function of global solar energy (Gat 1996) which is the heat derived from the sun, and is subject to long-term variation due to solar activity and earth's orbital cycles (COHMAP 1988). Changes in solar energy influence atmospheric temperatures as well as the extent of polar ice-sheets, and thus solar energy influences oceanic temperatures. Fractionation proceeds more slowly over colder marine water and in colder climatic conditions, so that the atmospheric water is less depleted in ^{18}O than over warmer seas and in warmer climates.

In the next stage of the hydrological cycle, the atmospheric water is circulated in accordance with atmospheric circulation patterns. These are influenced by oceanic and atmospheric temperatures, and contribute to patterns in seasonality, temperature, precipitation and vegetation on land (COHMAP 1988, 1050). As clouds move over the land, the cloud vapour condenses due to reduced temperature and greater altitude, and the heavier isotopes are preferentially 'rained out'. The rate of depletion in $\delta^{18}O$ values varies with the rate of precipitation, which in turn is a function of temperatures in high and mid-latitudes (but not in monsoonal lower latitudes) (Dansgaard 1964). The temperature effect may be expressed as: 0.58‰ depletion in ^{18}O per ˚C fall in surface air temperature (Rozanski *et al.* 1992, 984). The temperature effect holds true with altitude (Siegenthaler & Oeschger 1980); there is a near-linear empirical relationship throughout the world (at altitudes <5000m) of −0.28 ‰ per 100m (Poage & Chamberlain 2001, 5).

The moisture remaining in the clouds becomes increasingly depleted in the heavier isotope with the more distance it is from the oceanic source: this is reflected in precipitation that has increasingly lower $\delta^{18}O$ values the further inland it falls (Dansgaard 1964). Data collection

(Dansgaard 1964; Rozanski *et al.* 1993; Yurtsever & Gat 1981) establishes an empirical relationship, viewed as a measure of the average degree of rainout of moist air masses transported from the major vapour source regions to the site of precipitation (Darling *et al.* 2006, 9). In areas with simple weather systems, the $\delta^{18}O$ values in meteoric water inland of a mountain divide reflect the depletion associated with altitude (Blisniuk & Stern 2005, 1036). The rate of increasing depletion correlates well with increasing latitude in high and mid-latitudes (Yurtsever & Gat 1981, 113): −2‰ $\delta^{18}O$ per 1000km from the oceanic source (Rozanski 1985). The Meteoric Water Line (MWL) gives the correlation of deuterium and ^{18}O content of freshwater on an annual global and regional scale, the best line of fit being: $\delta D = 8\delta^{18}O + 10$ (Craig 1961).

The temperature and precipitation rate effects hold seasonally, so that the meteoric water in colder, wetter months has more depleted $\delta^{18}O$ values than warmer, drier months. Worldwide, the monthly precipitation has been shown to properly reflect the mean monthly isotopic composition of the atmospheric vapour (Darling 2006, 7). There are significant deviations from the MWL on a seasonal scale. In the first instance these are derived from seasonal differences in temperature and precipitation rates associated with the prevailing weather system (Darling *et al*. 2006, 12; Rozanski *et al.* 1993). The ^{2}D and ^{18}O correlation at a local and seasonal level is termed the Local Meteoric Water Line (LMWL), in which the slope is usually lower than 8 (Yurtsever & Gat 1981, 132).

7.4. Oxygen isotopes in terrestrial water

Meteoric water falls on the land as surface water. It might accumulate briefly on leaf surfaces or in small puddles, ponds or wetland areas before finding its way into perennial streams or mixing with older water in larger lakes. Ultimately meteoric water might become ground-water, mixing with longer-residency waters in underground reservoirs or aquifers (Gat 1996). In ground-water the mixing effect of previous ground-water, river water and

rainfall is complex, and the isotopic signal hard to interpret (Darling *et al.* 2006, 27), whereas in smaller bodies of surface water, isotopic signatures are highly seasonal. However, inter-annual variation in small bodies of surface water might arise from brief shifts in atmospheric circulation patterns. Flash floods originating uphill have more depleted signatures than local rainfall (Gat 1996), but are very short-term events (Darling *et al.* 2006, 25). Melt from heavy snowfall might initiate a pulse of depleted values that move slowly downstream; the time scale might be great enough to be measurable in monthly records (Darling *et al.* 2006, 25).

The most important effect on longstanding surface water, such as lakes, derives from evaporative conditions in hot, dry seasons (Darling *et al.* 2006, 28). Now the lighter isotope preferentially transfers as vapour, leaving liquid water, now enriched in the heavier isotope; this results in $\delta^{18}O$ values above those in the precipitation source (Gat & Gonfiatini 1981); in saline water bodies, however, evaporation is slightly inhibited by thermodynamic effects (Gat & Gonfiantini 1986). In more arid regions, enhanced evaporation is the main contributor to the lower slope of a Lower Meteoric Water Line (Yurtsever & Gat 1981, 132).

Within leaves, fractionation of transpired water on the leaf surface enriches the leaf-water; this effect is termed evapo-transpiration and can quite significantly enrich isotopic signatures compared to meteoric water (Flanagan *et al*. 1991). However stem-water is less evaporative and has values that approach those of meteoric water (Yakir 1992).

7.5. Oxygen isotopes in present-day central Anatolia

The central Anatolian climate and hydrology for the present day and during the Neolithic have been discussed in *Chapter 5*; in this chapter they are revisited to investigate the fractionation history of the oxygen isotopes in water that might have been ingested by sheep. The Global Network for Isotopes in Precipitation (GNIP), jointly operated by the

International Atomic Energy Agency and the World Meteorological Organisation (IAEA/WMO 2006), has collected monthly data from meteorological stations around the world since 1960. The data include temperature, precipitation, evaporation rates and deuterium and oxygen isotopic δ values. The GNIP Ankara records represent regional patterns in central Anatolia.

Meteoric water in central Anatolia ultimately derives from the Atlantic Ocean, and is carried over the Mediterranean Sea and onto the Anatolian mainland, where it falls predominantly between December and March (Rindsberger *et al.* 1983). The weather system is bound by the North Atlantic Oscillation (NAO) to the north and the Inter-Tropical Convergence Zone (ITCZ) to the south (Stuiver *et al.* 1995). The NAO influences winter weather patterns; it is the north–south variability in storm strength and trajectory across the Atlantic. The ITCZ influences summer weather patterns; it is the region where trade winds converge, forming a near-continuous band of clouds near the equator that are associated with summer monsoons (Gat 1996, 243). The seasonal influence of these systems varies with global solar energy levels, changing the trajectory over the Mediterranean; the exact trajectory is one of the prime factors determining oxygen isotope signatures in Anatolian meteoric water (Rindsberger *et al.* 1983, 43).

The air crosses the Taurus Mountains on its inland path to central Anatolia. In winter and early spring, the mountains receive *c.* 1000mm/yr precipitation on their coastal slopes and uplands; they act as a physical barrier reducing precipitation to <250mm/yr on the Konya Plain (Fontugne *et al.* 1999, 586). At this time of year temperatures can fall to −20 °C (Fontugne *et al.* 1999), and a weighted mean $\delta^{18}O$ value of −12‰ for January (IAEA/WMO 2006) reflects these depleted environmental conditions. In contrast, summer temperatures can rise to 30 °C in July and, as there is no rain in this season, there is a net evaporation of 800mm/yr (Kuzucuoğlu 2002, 38); $\delta^{18}O$ values are now considerably enriched to −4‰ (IAEA/WMO 2006).

The GNIP data show that central Anatolia has a persistent pattern of highly seasonal temperatures and precipitation. The relationship between $\delta^{18}O$ values in precipitation and temperature comply with Dansgaard's formulation (*above*), where $\delta^{18}O_{ppt} = 0.312T_{max} - 13.2$ (Jones *et al.* 2007, 467). The oxygen annual weighted mean of −8.4‰ is indicative of central Anatolian meteoric water being persistently sourced from the warm, highly evaporative Mediterranean Sea; the east Mediterranean Lower Meteoric Water Line is given as: $\delta^{2}D = \delta^{18}O + 22‰$ (Gat & Carmi 1970, 3059).

Sheep can meet almost all their water needs from seasonal precipitation on leaf surfaces or incorporated within leaves as leaf-water (Silanikove 2000, 14) and consequently, on the arid, highly evaporative Konya Plain, evapo-transpiration is an important consideration in charting the environmental conditions of oxygen isotope signatures in their body tissues (Iacumin & Longinelli 2002, 217). Models that trace the evapo-transpiration contribution have been proposed (e.g. Edwards 1993; Muller 1982), but have not been applied to the central Anatolian environment even though evapo-transpiration water loss in cereal crops has been determined for the Çatalhöyük locality (Janssen 1972).

Within a day's walk from Çatalhöyük there are bodies of water where the $\delta^{18}O$ values might not have the usual highly seasonal signatures. As an example, Pınarbaşı is a karstic spring where the water largely derives from underground aquifers. As the seasonal water is mixed, Pınarbaşı is likely to have $\delta^{18}O$ values close to the annual average throughout the year (Leng *et al.* 1999).

7.6. Oxygen isotopes in the Neolithic of central Anatolia

Global climate change has been recorded in ice cores, marine and terrestrial sediments, tree rings and in speleothems. Greenland ice-core records with a 20-year resolution now extend back to 16,500 cal. BP (Darling *et al.* 2006, 14). Holocene post-glacial global warming, after

the Younger Dryas downturn, proceeded until the mid-6th millennium BP. Towards the close of the Neolithic occupation of Çatalhöyük, there was a brief downturn in the global climate, 'the 8.2k event', probably provoked by a pulse of cold water from ice-shelf collapse. Originally thought to be a decade-long event, close analysis of the GISP2 ice core (Greenland Ice Sheet Project 2) and dendrochronology sequences now suggest it lasted >160 years (*Figure 7.1*) (Thomas *et al.* 2007, 78). In fact, the event might have been embedded in a longer period of cooling between 8.6 and 8kyr BP, related to sun-spot activity (Rohling & Pälike 2005, 978).

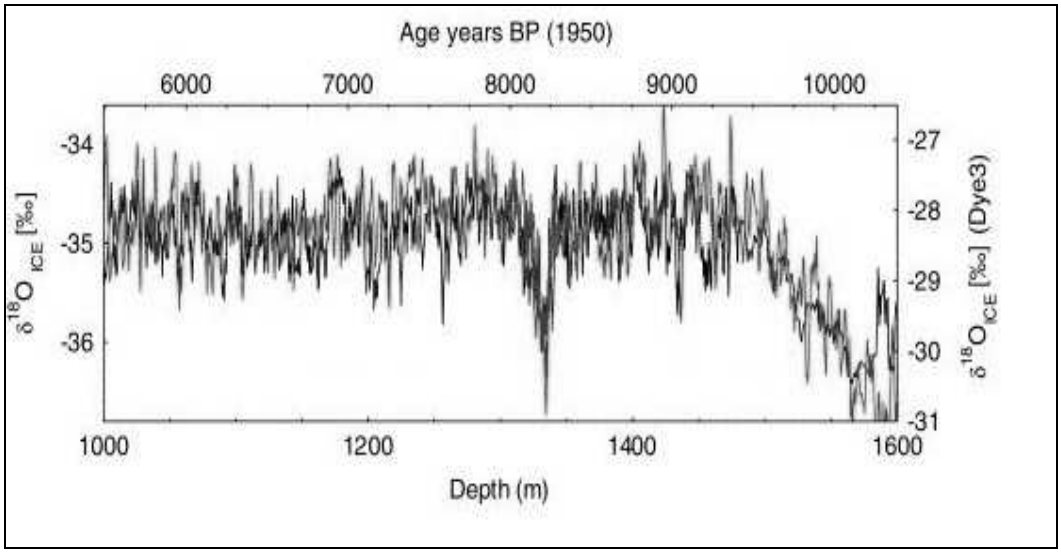


Figure 7.1
GISP2 ice-core showing Holocene warming (to the right), and the 8.2K cooling event (in the centre)
Thomas et al.*2007, 73*, Fig. 2

The response to global warming in any one region is a function of previous environmental conditions, changes in the air circulatory systems, and in seasonal patterns in the precipitation to evaporation balance. In order to understand direct evidence of $\delta^{18}O$ values in the past, the degree of resolution of the evidence is of equal importance to an assessment of all contributing factors. Changing environmental conditions in the Mediterranean Sea between 9500–6600 cal. BP were consistent with Holocene global warming and, as

temperature gradients between different basins were similar to today, it is argued that the air circulatory patterns were operating within the same parameters (Emeis 2000) (*Figure 7.2*). Ice-melt volume was such that, although there was a post-glacial rise in sea surface temperatures, they remained 1–2 °C lower than today despite the greater solar energy. Coinciding with the sea surface-temperature rise, between 9500 and 6600 cal. BP, there was a sapropel formation event, S1 (Rossignol-Strick 1999). Sapropel is organic-rich sediment formed when there is a change of depositional mode as a function of the evaporation–water-input balance; Rossignol-Strick (1999) ascribes this depositional change to an increased volume of snow-melt run-off.

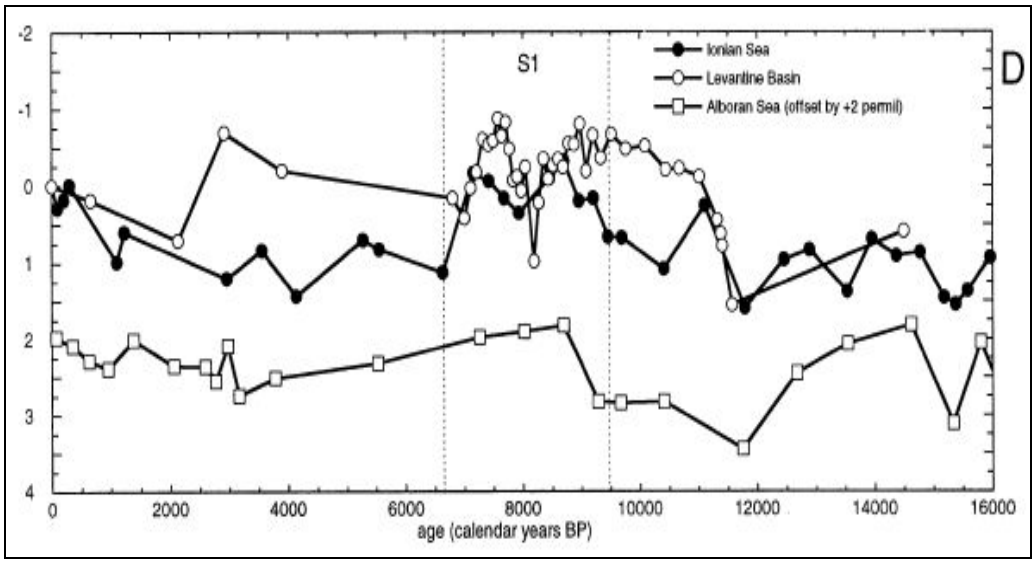


Figure 7.2
$\delta^{18}O$ values in three Mediterranean Basins during the Holocene. The y-axis shows $\delta^{18}O$, S1 is the sapropel 1 event.
Emeis et al. *2000, 272,* Fig. 5

Bar-Matthews *et al.* (2003) compare $\delta^{18}O$ values in the Soreq Cave speleothems, south Levant, with those in marine foraminiferae to show that precipitation $\delta^{18}O$ values over land have followed changes in the Mediterranean seawater for the last 250ky (*Figure 7.3*). In the early Holocene, the speleothem $\delta^{18}O$ values were −7 to −6‰, compared to −6 to −5‰ today, and are evidence of greater precipitation during the climatic optimum (Bar-Matthews *et al.* 1997, 159).

The pattern of chronological change in multi-proxy evidence from lake cores and water levels in Eski Acıgöl, central Anatolia (*Figure 7.4*), strongly suggests that global solar energy was the driving mechanism (Roberts 1991; Roberts *et al.* 2001). The early Holocene saw a rapid rise in water levels over a 1000-year period, but $\delta^{18}O$ values of the lake water were more depleted by *c.* 4‰ between 12,000 and 7000 BP than today (Roberts *et al.* 2001, 237, 732). These trends are echoed in evidence from Lake Van sediment cores, confirming that patterns were regional rather than local (Jones & Roberts 2008, 3; Wick *et al.* 2003).

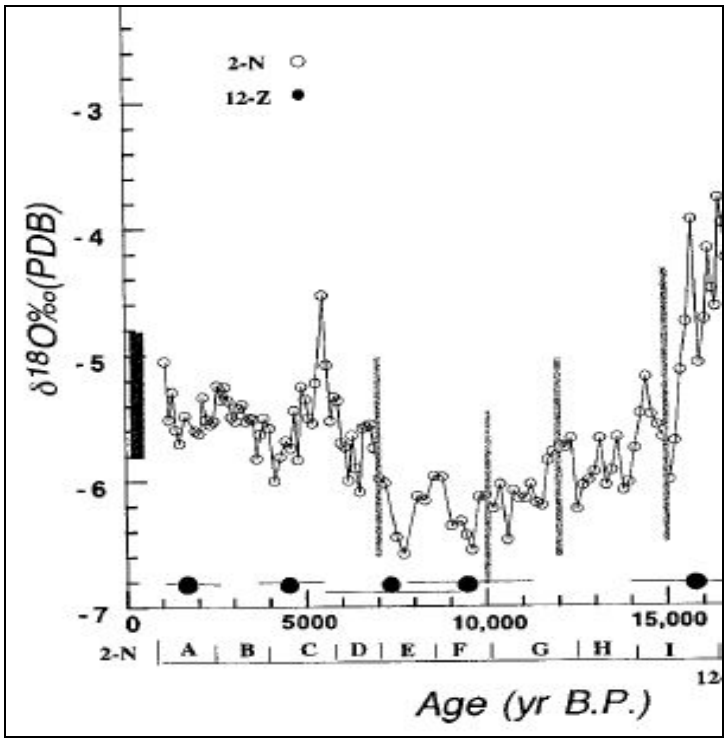


Figure 7.3
$\delta^{18}O$ values in Soreq cave speleothems during the Holocene.
Bar-Matthews et al. *1997, 159,* Fig. 4a

It might be expected that increasing temperatures would alter the evaporation to precipitation balance in favour of greater evaporation, leading to enriched $\delta^{18}O$ values. However, Jones & Roberts (2008, 35) convincingly argue that evaporation would have released moisture in post-glacial conditions, thereby increasing atmospheric humidity. As the climatic optimum progressed, moisture levels would have fallen, shifting the evaporation-to-precipitation balance and leading to greater aridity. Support for this proposal

might be seen in the slight trend in $\delta^{18}O$ depletion seen in *Figure 7.5* (Roberts *et al.* 2001,732), and also in common trends seen in Holocene oxygen isotope evidence in Konya Plain water bodies (Leng *et al.* 1999, 202).

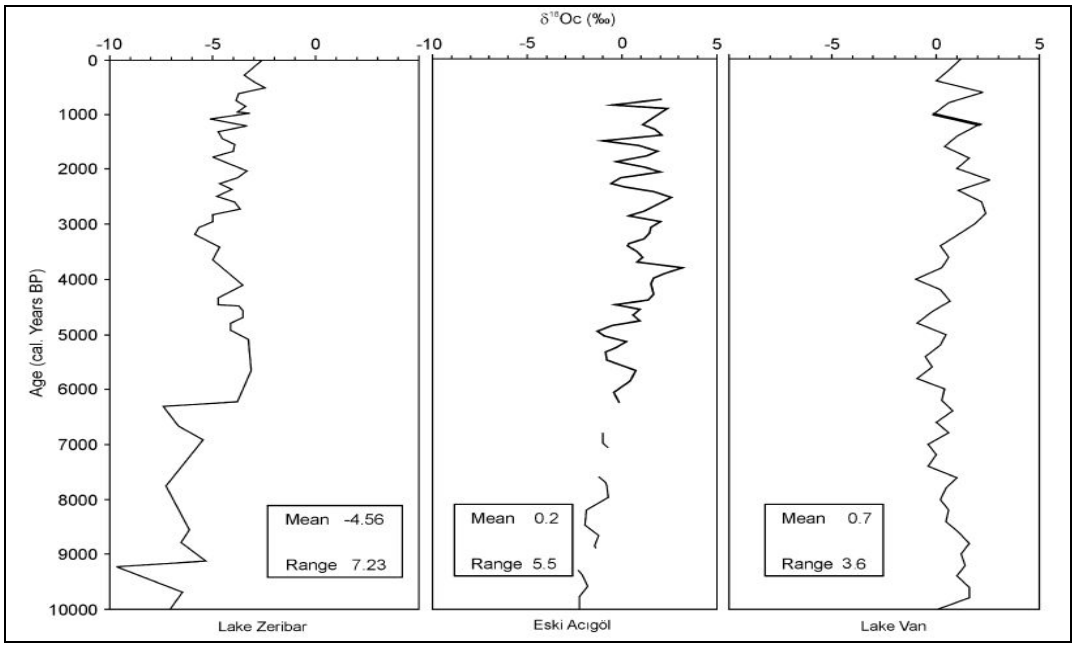


Figure 7.4
Oxygen isotope readings from three lake sediment cores. Eski Acigöl, in central Anatolia, has lower $\delta^{18}O$ values than today.
Jones & Roberts 2008, 3, Fig. 2

The seasonality of increased temperatures and precipitation in Anatolia during the climatic optimum is the subject of continuing debate, primarily because evidence from pollen records does not coincide with those from other temperature and rainfall proxies. Vegetation trends during the climatic optimum were discussed in *Chapter 5*, but for present purposes discussion is restricted to the effects of seasonality on $\delta^{18}O$ values. High winter humidity and summer aridity would have given, respectively, depleted and enriched seasonal $\delta^{18}O$ values when compared to today, whereas less seasonality in moisture distribution would have dampened seasonal $\delta^{18}O$ signatures.

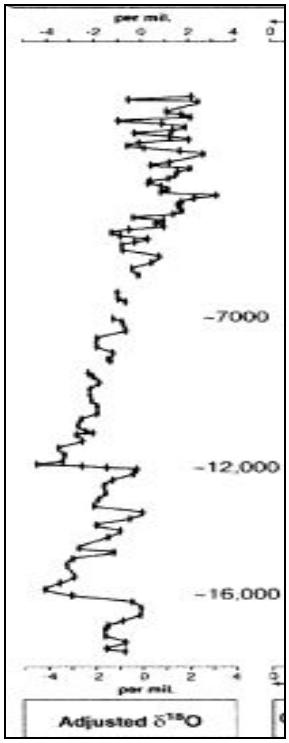


Figure 7.5
$\delta^{18}O$ values in Eski Acigöl lake sediment core.
Roberts et al. *2001, 732,* Fig. 7a

Wick *et al.* (2003) argue in favour of greater seasonality until 'the 8.2k event' heralded a change to reduced seasonality. They are supported by modelled palaeoclimate reconstruction by COHMAP members (1998), who suggest that at 9kya the average solar radiation over the northern hemisphere was 8% higher in July and 8% lower in January than today; this heightened seasonality then began to decrease. In opposition, Jones and Roberts (2008) argue that the degree of $\delta^{18}O$ depletion seen in lake cores can only be explained by less evaporative summer conditions, and Rossignol-Strick (1999, 528) suggests the pollen record supports a sub-humid climate with frost-free winters.

7.7. Summary of oxygen isotopes in water

There is wide palaeoclimatological evidence of an increase in solar energy after the last glacial maximum, leading to a climatic optimum coincident with the period of first settlement at Çatalhöyük. Around the time the Neolithic occupation of Çatalhöyük was

abandoned there was deterioration, if not a sharp downturn, in temperatures. However the air circulation patterns then were similar to those today and can be linked to precipitation patterns over southwest Asia in general, and Anatolia in particular. It is possible to use modern $\delta^{18}O$ values to calibrate the air temperature where there is evidence of little dramatic climate or temperature change and where the air circulation pattern is similar (Fricke & O'Neil 1999).

However, climate change has different effects at the local level (Fricke & O'Neil 1999), and the evidence of increased precipitation accompanied by depleted $\delta^{18}O$ values can be explained within two different models of climate seasonality. These suggest different evaporative inputs which would also be reflected in leaf-water evapo-transpiration effects. It is beyond the scope of this thesis to determine these effects, although an awareness of them can be useful in placing qualitative constraints on interpretation.

In summary, modern data may usefully model seasonal patterns of environmental conditions that may be used to interpret archaeological data. However, because evapo-transpiration effects are not modelled, archaeological oxygen isotope data will not be used to attempt to determine the Neolithic palaeoclimate at Çatalhöyük.

7.8. Oxygen isotopes in mammalian tissues

Environmental stable isotope signatures are reflected in the food chain through incorporation into plant and animal tissues. Studies of tissues that grow without remodelling, such as hair and nails, show a response to dietary change within a few days (O'Connell & Hedges 1999; Sharp & Cerling 1998). When understood within the metabolic processes of uptake, it is possible to establish a relationship between data in the biological material and in the food chain.

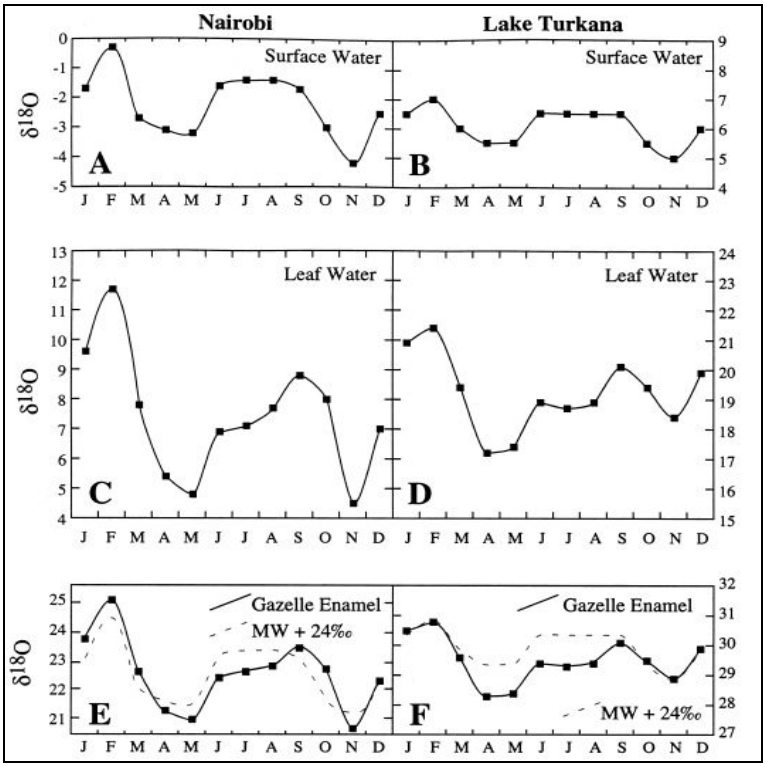


Figure 7.6
$\delta^{18}O$ values in surface water, leaf-water and gazelle enamel from Kenya, showing how enriched leaf water signatures are incorporated into surface water curves.
Kohn et al. *1998, 105,* Fig. 4

Oxygen in mammalian tissue is primarily derived from ingested water, producing a nearly linear correlation between $\delta^{18}O$ values in meteoric and body water (Longinelli 1984; Luz & Kolodny 1985). When atmospheric humidity is factored into the calibration it is possible to produce a closer correlation for mammals that source most of their water from leaf-water (Ayliff & Chivas 1988; Luz *et al.* 1990). Measured $\delta^{18}O$ values in meteoric water, leaf-water and gazelle body water from Kenya (*Figure 7.6*) show that values largely follow those of meteoric water, but with incorporation of the leaf-water signatures (Kohn *et al.* 1998, 105).

Longinelli (1984) argues that fractionation between drinking water and body water would be the same for all members of the same species. Empirical linear equations have been established for a number of species (e.g. D'Angela & Longinelli 1990; Luz & Kolodny 1985) and have been summarized (*Figure 7.7*) by D'Angela (1991).

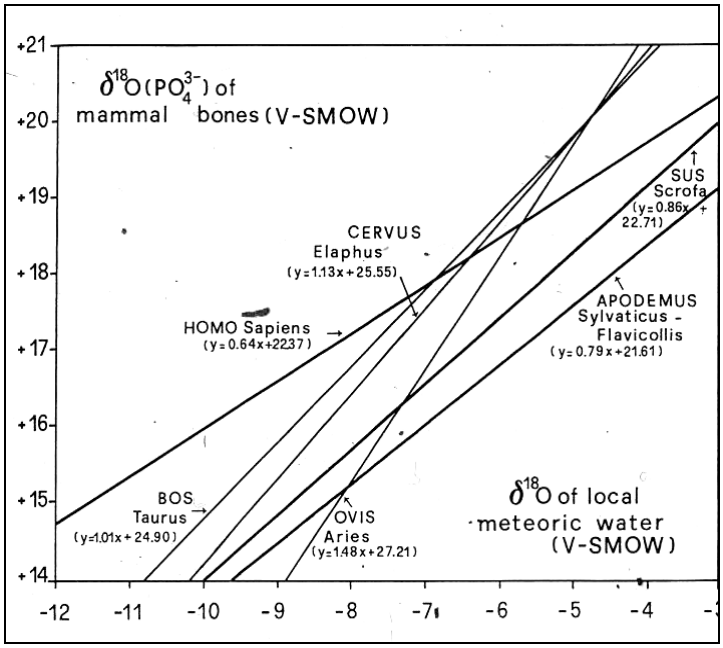


Figure 7.7
Relationship between meteoric water and bone phosphate $\delta^{18}O$ values in a range of mammals.
D'Angela 1991, 121, Fig. 1

Oxygen isotope values deriving from water intake far outstrip any vital effects relating to physical condition and energy expenditure. Luz *et al.* (1990) attribute the slight deviation from unity to the intake of atmospheric and food oxygen, previously empirically tested in rats (Luz & Kolodny 1985). Larger mammals have a slower metabolism than smaller species, and their water intake is proportionally greater than their food intake; this is modelled to show that they correlate more reliably with environmental information (Bryant & Froelich 1995). Kohn *et al*. (1998) warn that models might have temporal accuracy but lack compositional certainty, whereas the reverse is true of empirical data, due to physiological factors and methodological loss of resolution. They use empirical data to test both sets of uncertainties and find the empirical data fall within modelled boundaries, confirming that isotopic values in large mammals are primarily derived from the seasonality of environmental conditions rather than physiological variability (Kohn *et al.* 1998, 107). However, all animals will seek to avoid the worst excesses of environmental conditions, thus reducing the range of $\delta^{18}O$ values encountered (Hedges *et al.* 2008, 124).

Fractionation of oxygen isotopes occurs at different metabolic stages in biological uptake, and in large mammals has the advantage of taking place at a constant body temperature (Bryant & Froelich 1995). Oxygen isotopes in body water fractionate in a linear manner when incorporated into, for example, inorganic hydroxyapatite phosphate and carbonate components of teeth (Longinelli 1984). The largest component of each of these calibrations is a shift in values (Delgado-Huertas *et al.* 1995), which are constant intra-species (Fricke & O'Neil 1996).

7.9. Oxygen isotopes in sheep tooth enamel

The following section is restricted to details of tooth ontogeny, histology and physiology relevant to oxygen isotope analysis. Other aspects have been discussed in *Chapter 6*, or will be developed in *Chapter 8*.

Mature tooth enamel in living mammals is 96% inorganic hydroxyapatites, <1% organic proteins and the rest is water (Hillson 2005, 146). Hydroxyapatites are minerals, most commonly based on phosphate (96%) and calcium (4%), following the general formula $Ca_{10}(PO_4)_6(OH)_2$ (Hillson 2005). Enamel forms early in an animal's life and, unlike bone, is not remodelled later (Moss-Selentijn *et al.* 1997). Meteoric water incorporated into the phosphate and carbonate components of enamel should have $\delta^{18}O$ values that reflect the period of formation. The $\delta^{18}O$ values in the phosphate and carbonate components of tooth enamel may be converted into corresponding $\delta^{18}O$ values for ingested water, using calibrations for New Zealand domestic sheep proposed by D'Angela and Longinelli (1990) and Iacumin *et al.* (1996):

$$\delta^{18}O_{phosphate} = (1.48\delta^{18}O_{ingested\ water}) + 27.21$$

$$\delta^{18}O_{phosphate} = (0.98\delta^{18}O_{carbonate}) - 8.5$$

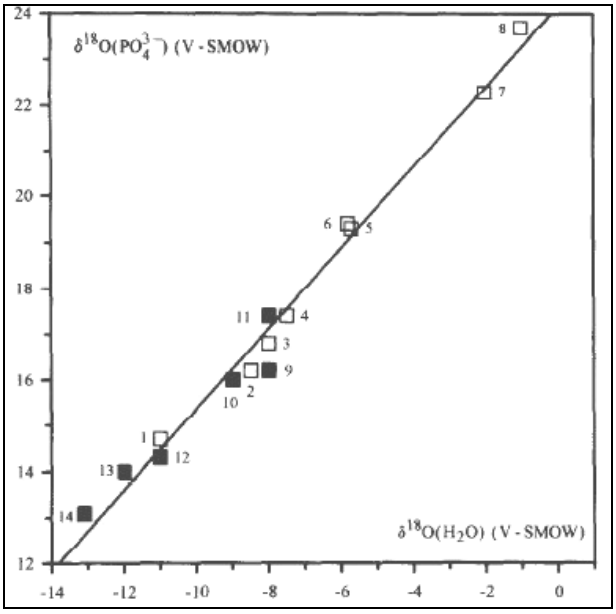


Figure 7.8
Relationship between meteoric water and bone phosphate $\delta^{18}O$ values in ibex (open squares), mouflon (open square N°5) and roe deer (black squares).
Delgado Huertas et al. *1995, 4301,* Fig. 1

Given their different feeding behaviour, surprisingly similar calibrations (*Figure 7.8*) are found in mouflon (*Ovis ammon musimon)*, ibex (*Capra ibex*) and roe deer (*Capreolus capreolus*) (Delgado Huertas *et al.* 1995, 4301):

$$\delta^{18}O_{phosphate} = (0.88\delta^{18}O_{ingested\ water}) + 24.1$$

Enamel formation is a complex process achieved in two broad phases. In the initial phase a weakly enamelised matrix is rapidly formed, incorporating only 10–20% of the final hydroxyapatite; on completion of this stage a longer phase of maturation and full enamelisation follows, accounting for 80–90% of the hydroxyapatite (Hillson 2005, 150). In sheep, the outermost 15–20μm of enamel forms in the maturation stage, taking twice as long as matrix formation (Suga 1982). Enamelisation is 87% complete soon after eruption and fully completed before occlusion (Sakae & Hirai 1982, 59).

At the enamel–dentine junction a layer of cells – ameloblasts – first produce a protein-rich matrix, thinly interspersed with inorganic crystals. In the second phase the ameloblasts switch function, now replacing the protein with larger, prismatic inorganic crystals (*Figure 7.9*) (Hillson 2005, 155; Moss-Salentijn *et al.* 1997, 5–22). Ameloblasts move in relation to one another, altering the direction of enamel production and producing complex patterns that are resistant to stress fracturing (Moss-Salentijn *et al.* 1997; Hillson 2005, 176). On a larger scale, ameloblasts in one region form production fronts, producing all the enamel in that region in a strict chronological sequence from the apex to the cervix of the tooth (Hillson 2005, 156; Moss-Salentijn *et al.* 1997). Rhythmical directional changes in the production fronts give a coarse layering to the enamel, observable as 'brown striae of Retzius'; their circadian nature has been established in human enamel (Moss-Salentijn *et al.* 1997; Hillson 2005 161).

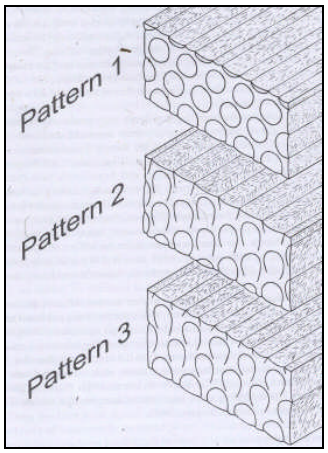


Figure 7.9
*Diagram of hypsodont tooth, showing prism pattern*ing.
Hillson 2005, 157, Fig 2.2

Sheep teeth, in common with many grazing ungulates, are hypsodont. The coarse layering of enamel builds downwards from the cusps in steeply inclined, overlapping sleeves, termed imbricational enamel (*Figure 7.10*); the brown striae breach the surface as wavy, linear troughs, termed 'perikymata' (Hillson 2005, 163; Moss-Salentijn *et al.* 1997). It would be possible to establish the periodicity of perikymata in order to age each part of the tooth

column. Timed feeding of C3- and C4- based diets in modern calves (Balasse 2003) and microradiograph- densitometry images of sheep-tooth longitudinal sections (Suga 1982) show that formation proceeds evenly from the tooth occlusal surface to the enamel–root junction.

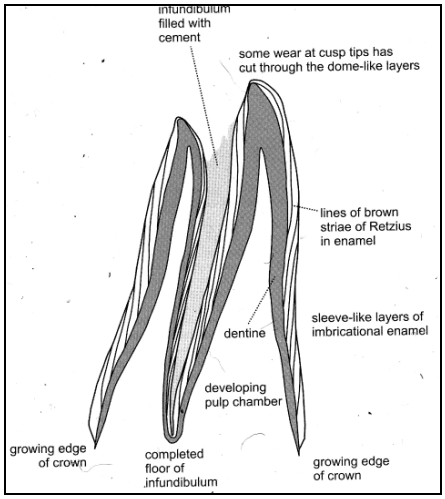


Figure 7.10
*Diagram of hypsodont tooth, showing enamel layer*ing.
Hillson 2005, 162, Fig 2.5

Enamel in the second mandibular molar (M_2) of sheep is precipitated from birth until one year old (Suga 1982; Weinreb & Sharav 1964, 898). Diet, disease, sex and stress can influence the exact timing and rate in children (Hillson 2005, 208) however; sex-led developmental differences are not established in other mammals (Hillson 2005, 210). Whilst Moran & O'Connor (1994) found variation in eruption times between living sheep breeds, developmental differences between individuals in one herd are also not established. Thus a sequential series of enamel samples taken down the tooth column of a sheep's M_2 (*Figure 7.11*) should provide approximately a one-year time capsule, in which the sequential $\delta^{18}O$ values may yield a curve for that year (Fricke & O'Neil 1996). Tooth wear removes enamel from the occlusal surface at a variable rate, and standardisation attempts have not met with full success (Hillson 2005). It has been shown that there is slight wear for a few months before full occlusion (Milhaud & Nezit 1991), probably as a result of food abrasion.

Consequently the earliest $\delta^{18}O$ values (*c.* birth in M_2) might be missing. However, the cervical-root junction provides a constant point (*c.* one year old in M_2) which constrains the interpretation of the time sequence of remaining $\delta^{18}O$ values (Fricke & O'Neil 1996).

Empirical work by Fricke *et al.* (1998, 1845) shows that curves produced from $\delta^{18}O$ values in tooth enamel clearly pattern seasonal $\delta^{18}O$ values of the ingested water (*Figure 7.12*), such that the signatures can identify latitudinal effects, inter-species ingestion behaviour differences, and the effects of tap-water and feed pellets associated with factory farming conditions.

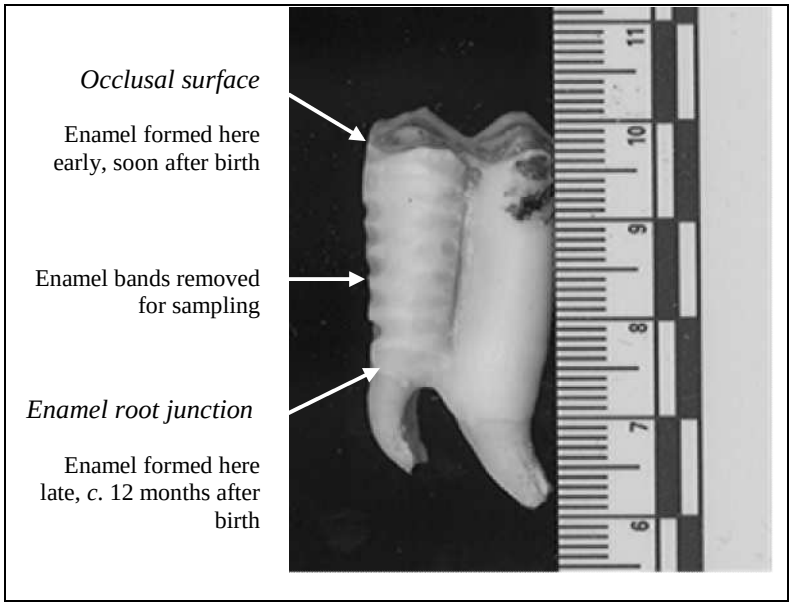


Figure 7.11
Photo of a sheep second mandibular molar with enamel bands removed for oxygen isotope analysis

However the $\delta^{18}O$ curves produced from sequential tooth enamel in sheep molars only pattern seasonal conditions; they do not give ingested water $\delta^{18}O$ values on calibration. Sampling precision has not yet succeeded in discriminating between the overlapping imbrication layers and the matrix layer in hypsodont teeth (Balasse 2003, 5). Thus, any sample cut perpendicular to the tooth column includes earlier and later material (Balasse

2002). In the feed trials mentioned above (Balasse 2003), C4 plants were introduced into the diet at ten months old, when the M_2 was two-thirds grown. *Figure 7.13* clearly shows the point of C4 feed introduction. However rather than an abrupt change mirroring the dietary change, there is a steady rise in $\delta^{13}C$ values beforehand, showing that enamel in earlier imbrication layers was still being precipitated six to seven months after each part of the tooth column appeared to be fully formed (Balasse 2002, 162). In summary, although $\delta^{18}O$ curves produced from sequential tooth enamel follow the $\delta^{18}O$ values of ingested water, they do not exactly replicate them either in temporal resolution or in amplitude of signal (Balasse 2002, 160).

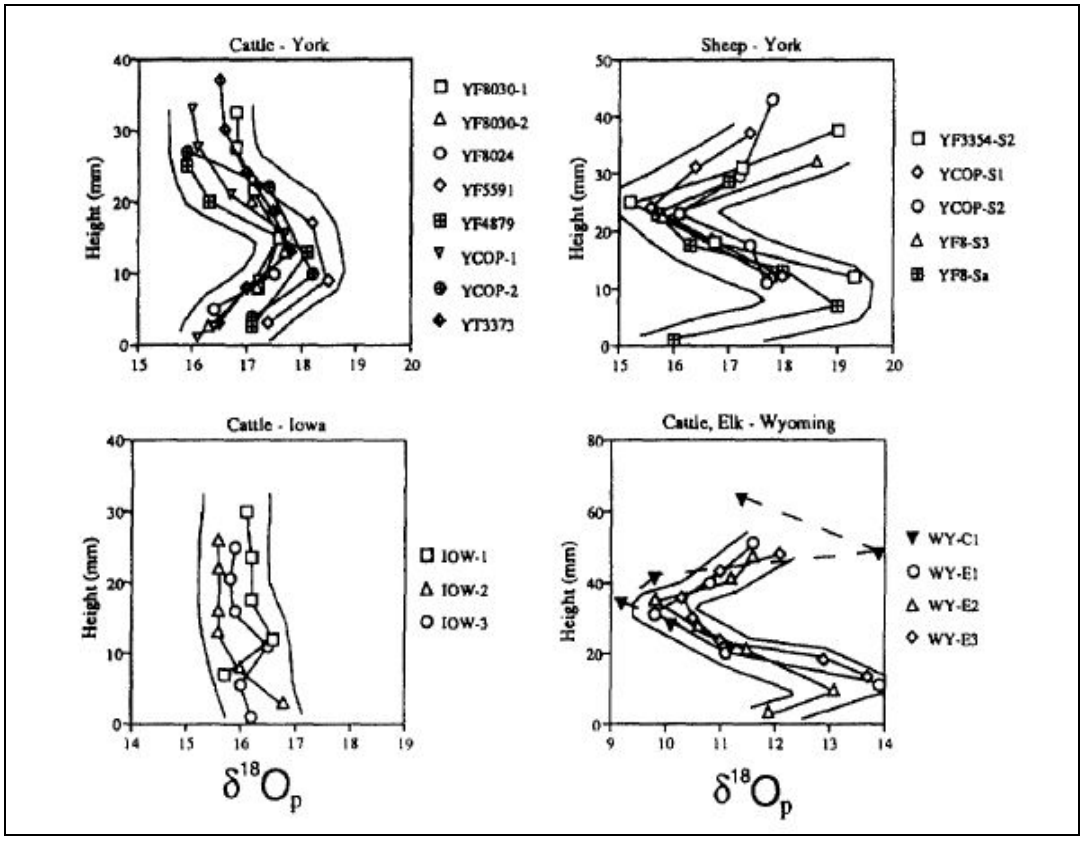


Figure 7.12
$\delta^{18}O$ values from sequential samples of enamel phosphate showing seasonal differences related to water ingestion behaviour in sheep and cattle from York, and in free-range and factory bred cattle from the USA.
Fricke et al. *1998, 1845,* Fig 3

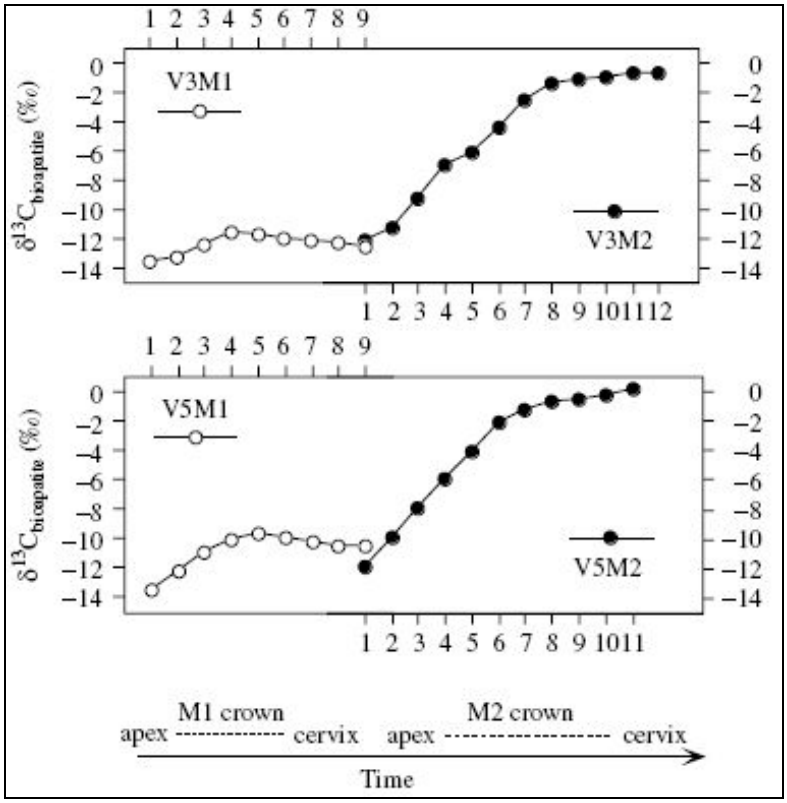


Figure 7.13
$\delta^{13}C$ values in first and second mandibular molars of calves, showing the introduction of C4 plants to the diet at nine months and the lag in full enamelisation of earlier imbrication layers.
Balasse 2002, 162, Fig. 3

The advantages of using tooth enamel in stable isotope studies, if only to pattern environmental conditions, partly stem from its early formation. However, this brings with it a potential disadvantage: before a young mammal is weaned it ingests maternal milk which derives from materials ingested by the mother. The stable isotope values will reflect the environmental conditions of the mother rather than the offspring, and in addition will be further fractionated on incorporation into the tissues of the suckling offspring. Calves raised for modern dairy-herd goals were rapidly weaned between nine and ten months old, and had nitrogen isotope values ($\delta^{15}N$) in their tooth collagen that clearly show (*Figure 7.14*) the associated change in trophic levels (Balasse & Tresset 2002).

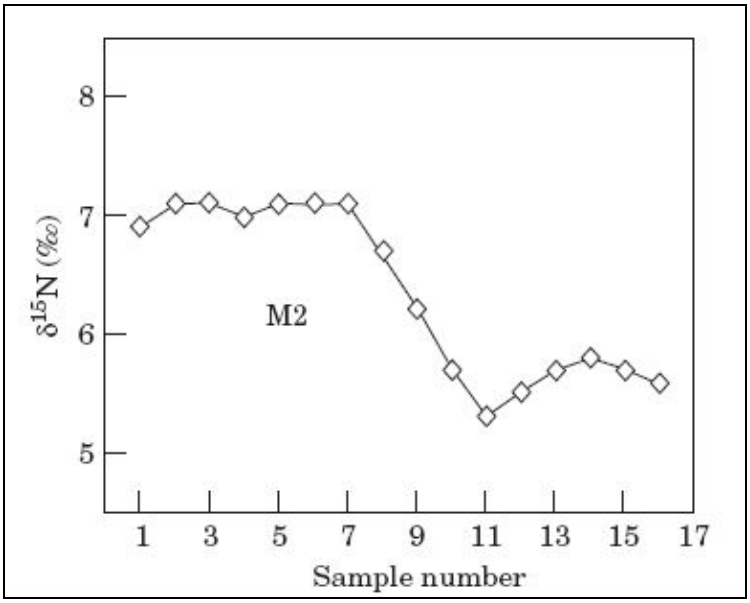


Figure 7.14
δ^{15}N values in a second mandibular molar showing the change (between sample 7 and 9) in trophic level associated with weaning.
Balasse & Tresset 2002, 856, Fig.2

Traditionally raised lambs, especially those raised for meat, have a less abrupt weaning pattern than dairy-herd calves. Lambs start eating grass by one week old and steadily replace the contribution of suckled milk to their diet by as early as four months (Dahl & Hjort 1976). Grant's gazelles are also medium-sized bovids with similar weaning behaviour (Kohn *et al.* 1998, 102); their natural habitat in African savannah more closely resembles that of Anatolian sheep than modern north European calves. Kohn *et al.* (1998) argue that the higher juvenile metabolic rate is linked to the need to excrete excess water from the suckled milk diet. Their modeled empirical δ^{18}O data show that suckling effects deplete δ^{18}O values by <0.5‰ whereas raised metabolic rates enrich δ^{18}O values by approximately the same amount. They argue that the effects serve to cancel each other out and, in any case, decline as solid food consumption increases, such that there would be an insignificant shift in isotopic signature.

Nevertheless, where possible, third mandibular molars are used as in sheep they form after weaning (Sharp & Cerling 1998). However, as 80–90% of enamelisation takes place in the

last six months of M_2 development (Balasse 2003), after natural weaning has occurred, the milk fractionation effect on $\delta^{18}O$ values in sheep M_2 can be considered insignificant.

7.10. Oxygen isotopes in archaeological sheep tooth enamel

Archaeological material has been resting in a sedimentary matrix since its original deposition; it is possible that it was susceptible to changing conditions in that matrix causing diagenetic changes to its original oxygen isotope signature. The organic component of bone and enamel has a poor survival rate (Wang & Cerling 1994), whereas the inorganic component survives for long periods because the minerals are stabilised during the fossilisation process (Lee-Thorp 2002). However, these very changes in the inorganic component might alter the mineral structure after death and burial; the isotopic signatures of the formation-environment might be obscured or obliterated in this process. Compared to bone, enamel has a lower organic content and its inorganic hydroxyapatite crystals are densely packed, porosity is only 1% compared to 40% in bone (Wang & Cerling 1994, 282). Tooth enamel is consequently more resistant to physical and chemical alteration, which is why enamel has become the material of choice in palaeoclimatology and archaeology (Fricke & O'Neil 1996, 91).

Oxygen in the phosphate component of enamel is practically inert (Kolodny *et al.* 1983); however the carbonate component is more susceptible to diagenetic replacement by carbonate-fluoro-apatites (Iacumin *et al.* 1996; Wang & Cerling 1994). Because preparation protocols and analytical costs favour stable isotope analysis of the carbonate fraction, it is advisable to run calibration tests on selected samples. The isotopic composition of oxygen in both components should be in equilibrium with body water, and so any deviation from a linear calibration of $\delta^{18}O$ values in each would warn of post-depositional diagenesis (Iacumin *et al.* 1996).

7.11. Summary of oxygen isotopes in sheep tooth enamel

The physiology and feeding behaviour of sheep suggests that the oxygen isotope composition of body tissues primarily derives from ingested water. In the Neolithic Çatalhöyük landscape (*Chapter 5*) the $\delta^{18}O$ values in ingested water were likely to have been highly seasonal, with ingested water $\delta^{18}O$ values close to those of the meteoric water in cooler seasons but highly enriched due to evapo-transpiration effects in the warmer season. Husbandry practices might have restricted the sheep's natural avoidance of seasonal extremes – moving to shady valleys or cooler altitudes, for example – and might have confined water intake to nearby highly evaporative water bodies with high salinity, to long-residency ground-water supplies or to stored water.

Physiological and ontological contributions to the oxygen isotopic composition of sheep enamel are limited, with minimal effects arising from further $\delta^{18}O$ enrichment in suckled milk. These variables become even less important in samples taken from healthy individuals in one herd, which have all survived into adulthood and were therefore probably all suckled when young.

The following factors preclude precise resolution of enamel $\delta^{18}O$ values with those of the ingested water. Firstly, animal behaviour tends to reduce exposure to extreme seasonal conditions. Secondly, there is a slight delay in the incorporation of meteoric water oxygen in body tissues. Thirdly, enamel precipitation proceeds in discontinuous stages introducing a time lag, which might be measured in months, between the environmental condition and its full representation in $\delta^{18}O$ curves of sequential enamel samples. Lastly, sampling precision is poor due to the overlapping imbrication layers in hypsodont teeth, and consequently seasonal values are dampened, or attenuated, by those from earlier and later periods. These inherent restraints limit the amount of information that may be extracted (Lee-Thorp 2008, 944).

The length of time represented in one tooth is dependent on the amount of material lost by occlusal wear, and the uniformity of development within species. In animals of similar age from the same species and herd, it can be argued that greater uniformity is more likely.

7.12. Modelling the contribution of oxygen isotope analysis

In summary (*Table 7.1*), oxygen isotope analysis of archaeological sheep tooth enamel, understood within the palaeoenvironment, provides a methodology that might contribute useful information on pre-historic herding practices. *Figure 7.15* models the way in which oxygen isotope data from archaeological and modern sheep teeth may be interpreted. The evidence will be used to approach herding seasonality and movement in Çatalhöyük breeding herds and fallow herds. Birth seasonality evidence will elucidate aspects of the management of herd parts designated for breeding including, by extrapolation, the mating season and associated seasonality of optimum resource provision required at different stages in the breeding cycle (*Chapter 6*). The evidence of seasonal movement will contribute to an interpretation of fallow herding practices; after the first two months of optimal pasturing and protection, lambs would be raised in fallow herds on less optimal pasture until designated for breeding or slaughter when fully grown and on reaching maturity. It should then possible to identify the likely seasonal locations of breeding and fallow herds in the Çatalhöyük landscape (*Chapters 5.5* and *6.4*).

- The sharp relief and extreme seasonal climate variation in the Çatalhöyük region should allow good discrimination between $\delta^{18}O$ values at varying altitudes and in different seasons respectively.
- The $\delta^{18}O$ values of modern meteoric water from central Anatolia (GNIP data) provide regional and seasonal patterns in climate that are relevant to the Neolithic.
- The $\delta^{18}O$ values in the carbonate and phosphate fractions of the same tooth may be calibrated to assess diagenesis in archaeological tooth samples.
- Inter-tooth differences in $\delta^{18}O$ enamel carbonate values can be assessed within expected inter-annual variations modeled by the 40-year GNIP record, and discussed in terms of possible effect of temperature, altitude and continentality.
- Intra-tooth sequences can be assessed starting from the cervical–root junction, taking the position of the highest and lowest $\delta^{18}O$ values to represent the warmest and coldest seasons of enamel formation, respectively, and the range of differences to represent the climatic extremes experienced by the sheep in its first year. The mean of the $\delta^{18}O$ values in the M2 represent yearly means, but can only be assessed in teeth with little wear.
- Movement of sheep to higher altitudes during the period of enamel formation would give a mix of signals that remain seasonal but do not reflect climatic conditions in one location; there would not be the expected annual curve.
- A modern comparator establishes the $\delta^{18}O$ values in sequential enamel samples from sheep with known birth seasons, and can identify the curve associated with the birth season and provide evidence of the expected time-lag in enamel formation
- A modern comparator establishes the $\delta^{18}O$ values in sequential enamel samples from sheep traditionally raised in different locations and at different altitudes in central Anatolia, and can identify local effects of altitude and aspect on seasonal $\delta^{18}O$ values.

Table 7.1

Summary of the contribution that oxygen isotope analysis of sheep tooth enamel might make to elucidating herding practices at Çatalhöyük

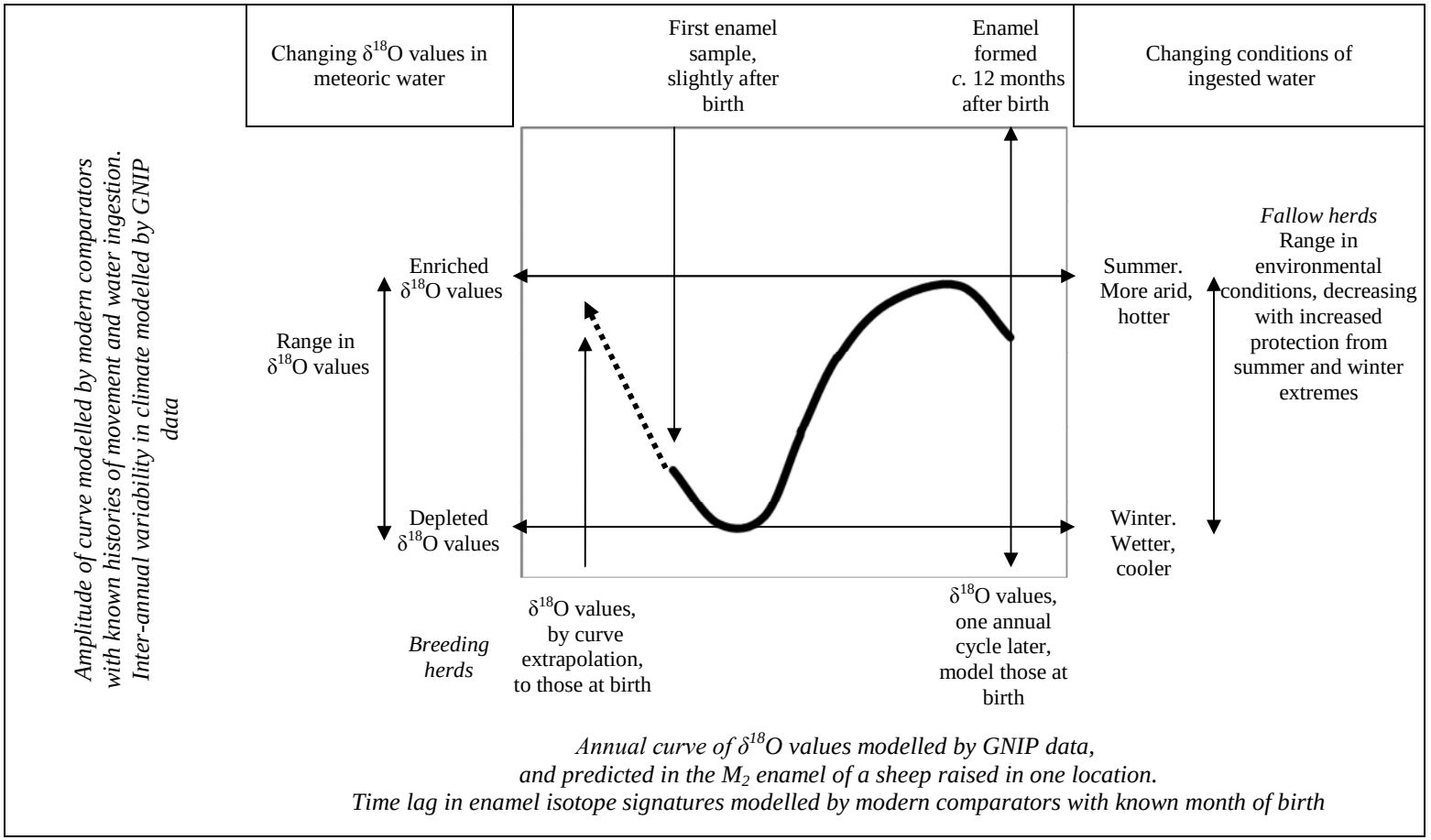


Figure 7.15
Modelled use of oxygen isotope evidence from archaeological and modern sheep teeth

CHAPTER 8. DENTAL MICROWEAR METHODOLOGY

8.1. Introduction

The previous chapter discussed the use of oxygen isotope values in tooth enamel as an evidential base for inferring the birthing regime and pasturing movement of Çatalhöyük sheep during their first year. The resolution of this direct evidence is such that each sheep is individually described. This is a powerful tool for the investigation of intra-settlement variety as well as the temporal and spatial trends that may be discussed in a wider regional context. In addition to sheep-birthing and herd-movement practices, evidence of sheep dietary regimes is centrally important to describing herd and resource management at Çatalhöyük. This chapter discusses the methodological foundations of a second dataset which also provides direct evidence at high resolution. Dental microwear has the potential to elucidate the dietary regimes of the sheep herd section destined for slaughter and consumption; the rationale for its choice was presented in *Chapter 1*.

Dental microwear analysis (DMA) is the study of small ephemeral defects, or microwear, on the enamel surface of teeth, and the direct relationship of these defects to dietary regime shortly before death. DMA is an attractive option as it can be applied to the same teeth as those used in isotope analysis. Dietary reconstruction should not depend on microwear evidence alone (Beuls *et al.* 2000b, 854) and its evidence of short-term feeding is better explored in conjunction with other evidence (Mainland 1998a, 60).

8.2. Previous palaeontological and archaeological application of DMA

In this thesis, the direction taken in the use of dental microwear analysis is based on its archaeological and methodological application to domestic caprine herding by Mainland (all references), and owes much to palaeontological enquiry. The establishment of comparative databases is an essential research component in DMA; these identify the dental microwear signatures associated with a range of diets. This section summarises interpretations that have been made using DMA evidence.

Dental microwear analysis was first applied to the diet of primates, used as marker of human evolution (Walker *et al.* 1978). It was then used by palaeontologists in their study of ungulate evolution and palaeoenvironmental change (Solounias & Hayek 1993; Solounias & Moelleken 1992); they instituted a database of microwear signatures in extant ungulates as a comparator to those in extinct species. A clear distinction was drawn first between microwear in grazers, leaf browsers and mixed feeders, and was used to investigate broad niche patterning, vegetation zones and seasonality (e.g. Solounias & Hayek 1993; Solounias & Moelleken 1992).

The comparative database expanded with the introduction of easier microwear recording methods (Solounias & Semprebon 2002) that give more precise data (Mercereon *et al.* 2004a). Dental microwear signatures can now be associated with refined browser–grazer divisions, allowing closer analysis of niche partitioning, and ungulate evolutionary pathways. Grazing signatures separate into C3 and C4 grass diets; browsing signatures discriminate between leaf-, fruit- and bark-dominated feeders; mixed feeders divide into those with seasonal, regional, and meal-by-meal dietary habits (Solounias & Semprebon 2002), where mosaic palaeoenvironments can be elucidated (Merceron *et al.* 2005, 181).

Dental analysis of tooth-cusp shape, or mesowear, uses a rapid recording technique that provides an extensive database of dietary signatures (Fortelius & Solounias 2000) and is shown to produce similar results to microwear (Solounias & Semprebon 2002, 38). Mesowear records long-term wear associated with life-long habitual diet, and can be used in conjunction with microwear signatures of short-term diet to identify seasonal feeding, food availability and chronological change in climate seasonality (Merceron *et al.* 2005).

The management of domesticates often entails a complex mix and a subtle variation in diet that differs from diets experienced by extinct ungulates. Mainland's work focuses on questions relating to caprine herding strategies, all of key interest to this thesis. She investigates microwear signatures associated with pasture grazing versus foddering; tree-leaf browse versus arable by-product fodder; access to fresh, seasonal food versus restricted diets of dried food-stuffs; grazing on good pastures versus degraded ones.

Mainland (2006) investigated seasonal resource management in Norse Greenland communities. First distinguishing summer and winter grass-rich diets (Mainland 2001, 85), she could then look for evidence of winter foddering versus overstocking on degraded winter pastures. Although it was common practice in the recent past to out-winter sheep on graze, it is a high-risk strategy where animals lose condition, and pastures become poached (Mainland 2001, 81). Microwear on adult teeth points to the sheep and goats having been grazed on sparse vegetation with muddy, poached soil (Mainland 2006, 246). However, the evidence suggests that, whilst kids also remained outside, lambs were over-wintered in stalls with clean bedding and fodder (Mainland 2006, 248). Toothwear stages support this interpretation, showing lambs were culled before winter, possibly to reduce foddering costs, whilst goats, possibly more able to survive winter, were culled when older and carrying more meat (Mainland 2006, 249). Mainland (2006) concludes that poor grazing practices contributed to settlement decline in Norse Greenland, alongside climate deterioration.

Neolithic Makriyalos, northern Greece (5400–4700 BC), has zooarchaeological evidence of domestic sheep, goat, pig and cattle exploitation (Mainland & Halstead 2002, 105). DMA can distinguish between caprines from general habitation layers and those from two large ritually situated pits; however it was not possible to separate sheep and goats (Mainland & Halstead 2002, 107). The DMA suggests that all animals were grazed in highly stressed pasture but that those from the ritual contexts were also given soft fodder (Mainland & Halstead 2002, 109). Their interpretation is that grazing might have been restricted to within-settlement enclosures, where most animals were destined for everyday consumption, but some were given supplementary diets leading up to their slaughter for special feasting.

Chronological changes in caprine dietary regimes in Roman Sagalassos, Turkey, were identified by Beuls (2004) as part of her study on the information that might be gleaned from sheep and goat assemblages. DMA applied to pig management distinguishes between stall-feeding and woodland-pasturing in Iron Age, Romano-British, Anglo-Saxon and Medieval Britain (Wilkie *et al.* 2007), and between pig-fattening strategies throughout the Classical occupation of Sagalassos (Vanpoucke *et al*. 2009).

Rivals and Deniaux (2003) studied chronological changes in the season of hunting argali wild sheep by Middle Stone Age inhabitants of southern France through grazing niche and climate change. DMA pointed to hunted sheep grazing on open grassy slopes in springtime when the grass was less abrasive than in autumn; modern hunters also confine their activities to this season. There were slight differences in microwear between two chronological levels, and as toothwear stages confirmed that the hunting season had not changed, Rivals and Deniaux (2003) argued that the differences must reflect chronological changes in climate and vegetation patterns. In similar research on hunting seasonality in three sites during the later Mousterian, Rivals and Deniaux (2005) investigated microwear signatures in the West Caucasian ibex and the Pyrenean chamoix. Comparing differences in dental microwear signatures to palaeoenvironmental information, they suggest that the ibex and chamoix had

been hunted in different seasons. Further work, investigated the length and season of Neanderthal site occupation by combining mesowear and microwear evidence (Rivals *et al.* 2009).

8.3. Functional morphology of sheep teeth

Various aspects of the morphology, histology and physiology of sheep teeth have been discussed in Chapters 6 and 7, and only those aspects that underpin dental microwear analysis are reviewed here.

Sheep dentition reflects their herbivorous diet rich in abrasive material, and also their evolutionary history. The teeth are high crowned (hypsodont) with relatively short roots, and the enamel is deeply folded into a sickle shape around a deep depression, termed the infundibulum; this gives rise to cusps, termed selenodont (Weinreb & Sharav 1964, 893) (*Figure 8.1*). Pre-molars and molars might have more than one pillar, such that the second mandibular molar has two pillars, each divided into buccal and lingual cusps (Weinreb & Sharav 1964, 899).

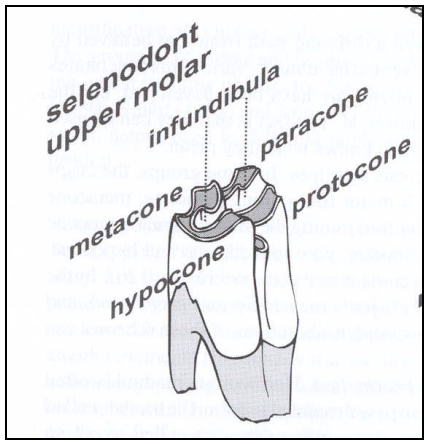


Figure 8.1
Diagram of a ruminant selenodont, hypsodont molar.
Hillson 2005, 16, Fig. 1.4

In order to maintain occlusion as the surfaces are progressively worn away, teeth continue to erupt for five or six years, pushed up by lengthening roots (Hillson 2005, 229). Cementum, attached to the teeth and to the gingival epithelium, helps to anchor the teeth to the gum (Weinreb & Sharav 1964, 896). The replacement of deciduous teeth by adult dentition allows occlusion to be maintained despite jaw and maxilla growth (Janis 1990, 243). The setting of the maxilla and mandible causes the occlusal surfaces to meet on an inclined plain where only the enamel crests touch (Weinreb & Sharav 1964, 894).The pre-molars and molars in both upper and lower jaws are aligned in a slight curve, presenting as one long body with high buccal and lingual surfaces (Weinreb & Sharav 1964, 895). As occlusal wear proceeds, alternating bands of hard enamel and softer dentine are revealed. The functional effect is a long, grinding, milling machine (Hillson 2005, 18) (*Figure 8.2*).

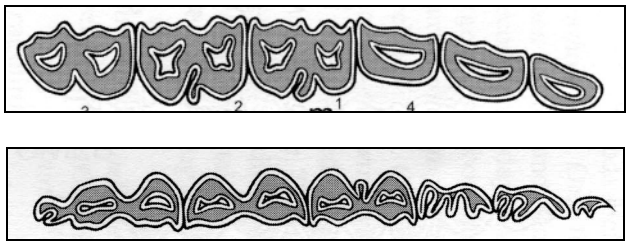


Figure 8.2
Diagram of the upper and lower occluding surfaces of ruminant teeth.
Hillson 2005, 141, Fig. 1.95

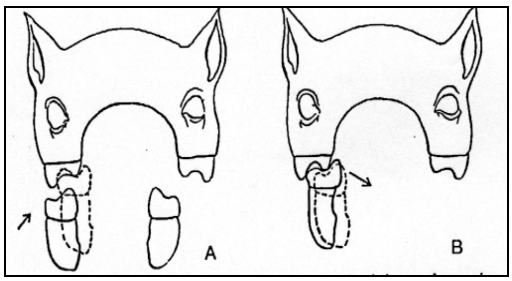


Figure 8.3
Diagram showing two phases of jaw action. (A) brief crushing movement. (B) long horizontal shearing action.
Janis 1990, 243

Functional dentition includes the surrounding cranial structures. Ungulate jaw action is predominantly horizontal, where the temporomandibular joint and the masseter muscle are specialised to allow a side-to-side swinging action (Janis 1990, 243). The mouth action may be split into different phases as the jaw moves in and out of occlusion (Janis 1990, 243). Phase one starts with a brief vertical crushing jaw movement which rapidly moves to a longer, horizontal shearing action (*Figure 8.3*), unless needing to tug on tough food such as woody browse (Janis 1990, 245). The horizontal shearing action is associated with rhythmic chewing and rumination, and proceeds across the tooth row from a well-defined buccal edge in a highly orientated fashion towards a more amorphous lingual edge (Janis 1990, 245). The second phase (*Figure 8.3*) brings the teeth out of occlusion and is less forceful (Janis 1990, 245). The regular shearing action gives rise to areas of accumulated wear on the enamel bands, termed wear facets (Janis 1990, 243) (*Figures 8.4* and *8.5*).

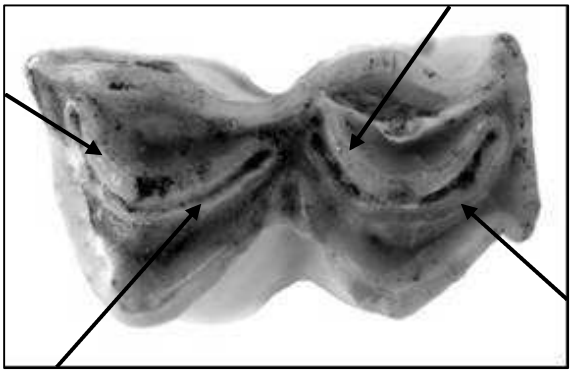


Figure 8.4
Occlusal surface of a sheep's second mandibular molar, showing enamel wear facets

Whilst unworn teeth tell of their capabilities (in ungulates they are designed for abrasive herbivorous diets), worn teeth give direct evidence of behaviour associated primarily with food intake (Teaford 2007, 124). Gross toothwear is the accumulation of polish, nicks, scratches and pits and reflects diet over a lifetime.

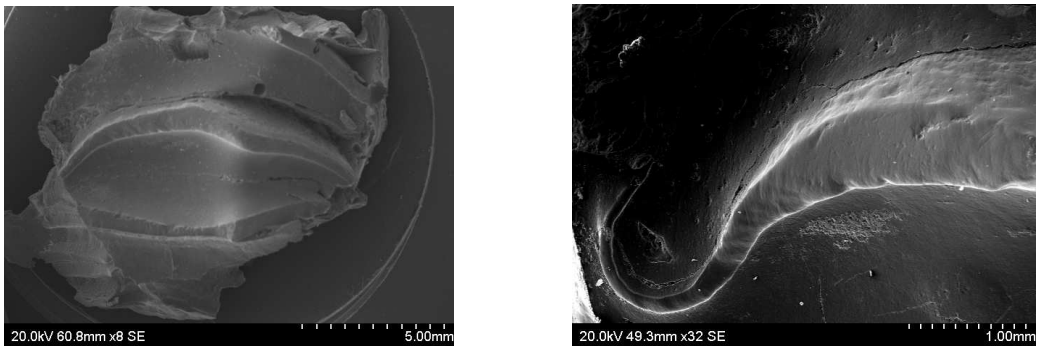


Figure 8.5
Wear facet on dental enamel of a sheep second mandibular molar.
Images captured at x8 (on left) and x32 (on right) magnification

There are two types of wear. Attrition is caused by tooth to tooth contact on cutting through food, and abrasion is caused by the movement of food over the tooth (Semprebon *et al.* 2004, 428). Abrasion tends to smooth and round off the leading edge, removing the sharp cutting edge needed for shearing, whereas attrition affects the slopes of the cusp, serving to re-sharpen the edge (Fortelius & Solounias 2000, 3) These processes are functionally the same along both upper and lower tooth-rows in all but unworn or very worn teeth, the resulting shape and height of the tooth cusps is termed mesowear (Fortelius & Solounias 2000).

Microwear is the term used to describe each wear event, and appears as scratches and pits of different dimensions and orientation; it also includes other categories, such as polish, chipped or flaked areas on the enamel surface. Chipping and flaking tend to occur on the edges of the wear facets, particularly where the underlying prism structure of the enamel is at it weakest orientation to food comminution stresses, and polish is often obscured by heavy wear and is most apparent where wear is light (Beuls 2004, 414).

The shape of microwear features (*Figure 8.6*) is a function of mouth action. Striations are caused by the abrasive action of trapped ingested material between the occlusal surfaces and are generally associated with chewing and rumination (Gordon 1984, 79). The mechanism of

pitting is varied and might be caused by attritional tooth-on-tooth contact as the shearing action cuts completely through softer ingested material; by vertically trapping harder abrasive material; or by biting down on non-abrasive but tough material such as wood or seedcases (Puech *et al.* 1981*;* Teaford 2007, 121).

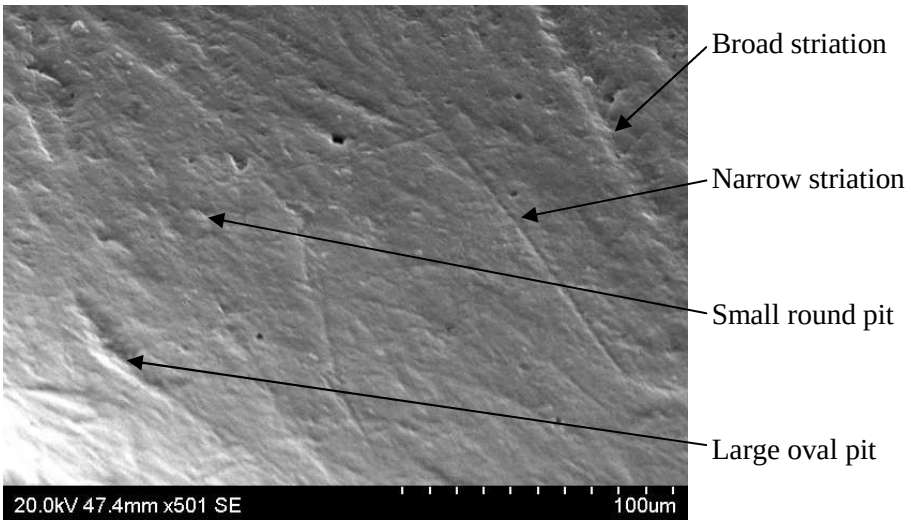


Figure 8.6
*Occlusal surface of enamel of a sheep 2nd mandibular molar showing area of microwear capture (*x500)

Early work on grazing and browsing ungulates showed a bimodal distribution of signatures in opportunist mixed feeders, suggesting a rapid turnover where microwear remains for only one or two days after the last feeding phase (Solounias & Moelleken 1992, 120). However, the unscheduled escape of two sheep from controlled feeding trials resulted in microwear that could be associated with diets eaten over a week earlier, suggesting that microwear has a relatively slow turnover in caprines eating leafy hay (Mainland 1998b, 1267).

Scratches decrease in number, and pits decrease in size, from the first to third molar in certain populations (Mainland 2006, 242), however, as they are in occlusion, upper and lower molars exhibit the same microwear (Billet *et al.* 2009, 19; Teaford & Walker 1984, 195). Once the tooth is old enough to be in wear, increasing tooth age has been shown not to affect wear until old age (Beuls *et al.* 2002, 342). Microwear differences between males and

females are considered to be primarily related to differences in seasonal diet or husbandry regimes, rather than to innate differences in tooth functional morphology or feeding behaviour (e.g. Nystrom *et al.* 2004, 281, *contra* Gordon 1982).

8.4. Dietary causes of dental microwear

The causes of microwear have considerable equifinality difficulties which limit close dietary reconstruction, in addition to archaeological questions of uniformitarianism and taphonomy. This is pertinent to the archaeological application of DMA because dietary differences in herd animals can often be subtle yet imply socially significant herding decisions. This section reviews research into the causes of wear most relevant to sheep.

Although strong general associations may be made between different feeding regimes, it is not yet certain what causes wear. Whilst mesowear is the cumulative effect of microwear pits and striations (Solounias & Semprebon 2002, 33), gross wear has additional causes. In ungulate diets there are three main wear candidates: plant phytoliths, grit or dust inclusions, and acid levels in ingested material. Acidity erodes the enamel amorphously (Teaford 1994, 21); both phytoliths and ingested grit might cause gross wear and microwear; phytoliths might contribute to surface polish; ingested grit might cause larger chips and nicks. This section focuses on the role of phytoliths and grit in microwear formation.

Acquiring empirical data from animals on controlled diets is hampered by animal-testing ethics, and by the lack of food-intake controls in non-laboratory animals (Teaford 2007, 112). An attempt to collect evidence by direct observation of sheep plant intake was thwarted by their shyness, and their practice of flocking closely whilst grazing vigorously with their heads down (Beuls *et al.* 2002, 341). It is necessary to take other approaches.

It has been assumed that the material causing microwear would need to be harder than enamel. On Moh's scale of resistance to scratching, both siliceous phytoliths in *Avena* sp. (5.5–6.5) and quartz grit particles (7.0) are harder than sheep tooth enamel (4.5–5.0) (Baker *et al.* 1959, 1584), whereas clay calcite particles (3.0) are softer (Beuls *et al.* 2002, 340). Measures of resistance to indentation, using the Knoop hardness scale, found that *Avena* sp. phytoliths measure 590–610, quartz particles are 710–790, and enamel varies between 382–270 (Baker *et al.* 1959, 1584). Therefore both phytoliths and certain grits might cause wear.

As sheep are estimated to eat 22lb of phytoliths per annum in their silica-rich grassy diet (Baker 1959, 1584), phytoliths, rather than grit, might be assumed to be the main cause of gross wear in hypsodont teeth. Phytoliths are commonly found in monocotyledonous plants such as grasses, reeds and rushes, but are far less significant in soft, dicotyledonous plants such as herbaceous forbs and woody shrubs. Therefore, in ungulates that ruminate on abrasive grasses, phytoliths might be expected to produce dental microwear rich in striations, whereas their absence would be apparent in the dental microwear signatures of vertically plucked or tugged soft browse. Such discrimination between grazing and browsing ungulates was observed in early research (Solounias & Hayek 1993; Solounias & Moelleken 1992).

In addition, phytolith-rich diets might be expected to cause greater wear rates than browse diets; Solounias *et al.* (1994, 223) measured a 2.93mm/yr tooth-height loss in grazing ungulates but only 0.33mm/yr in browsing species. Palaeontologists reviewed the evidence of the evolution of ungulate hypsodonty in order to approach the causes of toothwear. Early interpretation suggested that arid Miocene grasslands co-evolved with ungulate hypsodonty (Webb 1983), and it was assumed that hypsodont grazers flourished at the expense of brachydont browsers (Janis *et al.* 2002, 184). As these grasslands are associated with phytolith-rich C4 grasses (Kaufman *et al.* 1985; Reinhard & Danielson 2005), palaeontologists argue that phytoliths play the greater role in striation formation (Solounias

& Semprebon 2002).

Young grass shoots have fewer phytoliths than mature growth (Janis *et al.* 2004, 375) and C4 grasses have three times the phytolith content of C3 grasses (Merceron *et al.* 2005, 179); variation in associated microwear signatures might be expected. There is an association between wide striations and diets rich in larger phytoliths from open plains C4 grasses, and narrower ones from smaller C3 woodland grasses (Merceron *et al.* 2004a, b, 2005; Semprebon *et al.* 2004; Solounias & Semprebon 2002). Mesowear and microwear signatures confirm the succession ecology of arid grassland-grazing; they show that zebra first take mature, coarse C4 grasses, followed by wildebeest feeding on younger C4 grasses, and finally gazelle come through to feed on new soft, low-lying vegetation (Solounias & Semprebon 2002, 32).

However, the role of phytoliths in toothwear has been questioned by veterinary trials, which link high gross toothwear to high soil ingestion. Field and Purves (1964) established that sheep ingest soil with their food: up to 14% in muddy, over-stocked pastures but <1% in clean well-managed ones. Healy and Ludwig (1965) compared the soil content of dung to gross toothwear. Sheep from three farms could be distinguished by their gross toothwear and by the soil content of their dung. On farms identified by low, medium and high gross toothwear in their sheep, it was found that, respectively, 1lb, 10lb and 25lb of soil were ingested during four winter months (Healy & Ludwig 1965). The phytolith content of the dung, on the other hand, bore no correlation to wear (Healy & Ludwig 1965, 745). They concluded that soil ingestion is the greater contributor to wear.

Mainland (2003) explored the relationship between microwear and soil ingestion in her analysis of the inorganic component of dung collected from ungulates with known diets and microwear signatures. She associated less microwear with less soil ingestion in browsing Gotland sheep and more microwear with greater soil ingestion in grazers on muddy, sparsely

vegetated, unimproved pasture; however both groups had similar phytolith levels (Mainland 2003, 1523-4). In a further comparison between these grazers and a third group grazed on clean, non-stressed, improved pasture, phytolith levels again remained the same, but the amount of ingested soil and microwear was even less in the sheep raised on improved pastures (Mainland 2003).

If ingested grit is the cause of wear, then the amount of wear should vary with the proximity of grit to food. In temperate landscapes, high soil ingestion has been associated with ground feeding in winter conditions where worm casts, rain and sparse vegetation contribute to poached pastures (Healy & Ludwig 1965; Mainland 2003). In arid environments high grit levels have been associated with summer aridity on open plains where wind-blown grit is not washed off the leaves into the soil (Beuls *et al.* 2002; Janis 1990).

Ingested grit could also be expected to vary the type of microwear it causes, according to the type of food in which it is trapped. Pitting has been found to be low in tree-top browsers such as giraffes, where the soft leaves are relatively dust-free, and to be high in low-scrub browsers such as camels and pronghorn antelopes, where the phytolith-free vegetation is often covered in wind-blown dust (Solounias & Semprebon 2002). Striation numbers are low in the teeth of domestic caprines grazing in good summer conditions, and high in those grazing in bad conditions (Mainland 2003).

In summary, Solounias and Semprebon (2002) argue that phytoliths cause striations and grit causes increased pitting on dirty browse, whereas Mainland's (2006) caprine dung analysis confirms the importance of ingested grits in striation formation too. Reconciliation of these differences is limited. The dung evidence in caprines does not preclude a role for phytoliths in striation formation in other species, or in causing other forms of wear(Mainland 2006, 245), but, as yet, no analysis has been undertaken on dung rich in C4 grasses, nor on low-lying forbs favoured by sheep early in the growth season. Solounias and Semprebon (2002)

suggest that phytoliths might play a particular role in striation formation in C4 grass-rich diets, but, as yet, there are no controlled studies to test this.

There are also contradictory pieces of evidence that limit interpretation and require explanation. For example, the number of striations in C4 grass-rich diets is unexpectedly low, possibly as these wide features overlap and obscure each other (Solounias & Semprebon 2002, 36). The pattern of increasing striations in temperate domestic caprines does not give a linear correlation with ingested grit levels, possibly a certain threshold of ingested grit first has to be reached (Mainland 2003, 1524).

The central difficulty is that phytolith richness and grit quantity usually coincide. Mature plants, rich in phytoliths, are covered in dusty grit in arid summers, as are C4 grasses growing on open savannah plains throughout the growing season. In winter the remains of mature plants are surrounded by bare patches of exposed mud. On the other hand, grasses with fewer phytoliths grow in less gritty, dusty environments. Young C4 grasses grow more densely and are washed clean by seasonal rain, and C3 grasses grow in more sheltered areas less exposed to wind-blown material.

Further research questions the comparative hardness of enamel and its abraders. There is no relationship between toothwear and the hardness of ingested soil (Healy & Ludwig 1965, 739–741); sheep and goats grazing on calcite soil pastures have the same number of microwear features as those grazing on quartz-rich pastures (Beuls *et al.* 2002, 345). Recent work, using more precise measuring instruments and less invasive extraction techniques, on a modestly extended study of four grasses, suggests phytoliths are not hard enough to be the main cause of gross wear or microwear (Sanson *et al.* 2007). Converted to modern Vickers Hardness measures, silica is only 51–211 compared to Baker *et al.*'s (1959) assessment of 579–598, whereas enamel measurements of 257–397 remain in agreement (Sanson *et al.* 2007, 527). Yet, in contradiction, an approach that simulates human ingestion of different

cereal grains gives direct evidence of a pit shape associated with a species-specific phytolith (Gügel *et al.* 2001, 131). Both pieces of research could benefit from being enlarged with greater control of their variables.

Shape, as much as hardness, influences the ability to abrade. Angularity in certain grits and phytoliths is such that their pointed parts, where the cross-section narrows, might abrade the enamel surface. If striations are not caused by the whole abrasive particle, then Teaford's (2007) argument – that striation width should discriminate between phytoliths and grit – falls. As does Sanson *et al.*'s (2007, 528) argument – that the scratch width (±5μ) in their study is more consistent with the size of silt and clay particles (0.4–6μ) than with phytoliths (>10μ). In addition, inter-species variations in enamel microstructure contributes to differences in striation width (Maas 1991), further limiting the diagnostic use of striation width in DMA.

If the relationship between the shape and hardness of abrasives and microwear formation is more complex than first thought, so too is the association between ungulate hypsodonty and Miocene grassland evolution. More precise dating shows that the rapid decline in browsers was not due to evolving hypsodonty, de-coupling the evolutionary link between C4 grasslands and hypsodonty, and thus between phytoliths and microwear (Janis *et al.* 2002, 2004). The florescence of ungulates (*Figure 8.7*) is now shown to be largely due to a wide array of browsing species which persisted long after the inception of a grassland environment, alongside a smaller peak in the number of grazing species which emerged before the grasslands (Janis *et al.* 2002, 189; 2004, 380). It is now possible that hypsodonty is inherited from much older adaptations (Semprebon *et al.* 2004) and subsequently retained in some species to manage higher dust levels adhering to low-lying browse as aridity increased (Janis *et al.* 2002). The pronghorn antelope, for example, retains its hypsodonty despite a diet of soft, leafy browse that contains few, if any, phytoliths (Janis *et al.* 2002, 185).

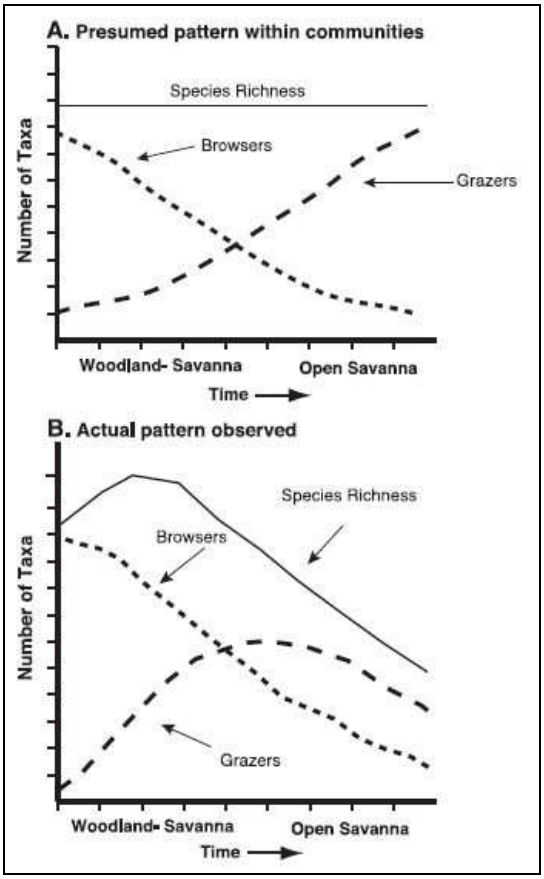


Figure 8.7
Diagram showing presumed and actual changes in ungulate species richness during the Miocene.
Janis et al. 2004, 373, Fig.2

It is extremely difficult to control the variables so that the cause of microwear signatures in each diet may be securely ascertained. Animals, even if dedicated to one feeding niche, take in other foodstuffs either inadvertently, or when under stress, and the composition and cleanliness of different parts of the plant can vary considerably (Solounias & Semprebon 2002, 33). Equifinalities in pit formation arise from attritional and abrasive wear, and in both pit and striation formation from the unresolved roles of grit and phytoliths. Caprine dung analysis has provided a clear relationship between striations and ingested grit in temperate climates, and provides the strongest evidence in certain conditions. Such an analysis can usefully be extended to a small, modern baseline directly relevant to this thesis, in order to disclose certain equifinalities of dental microwear signature.

8.5. Recording and quantifying dental microwear

Some of the greatest limitations in dental microwear analysis result from the way in which wear is recorded and quantified (Teaford 2007, 122). Quantitative methods can be used to record mesowear as well as microwear (Fortelius & Solounias 2000) and the results are shown to be complementary (Franz-Odendaal & Kaiser 2003). As mesowear recording methods are integral to the assessment of recording techniques used in microwear studies, they are referred to in this section, although not used in this research.

The most common method of image capture, the one used in this thesis, selects suitable samples and makes casts of dental impressions. Defined wear facets are viewed under a Scanning Electron Microscope (SEM) at *c.* x500 magnification and then captured digitally for analysis and quantification. It has the advantage of being a non-destructive technique which can make use of museum collections. However, preparation and image capture is a costly and lengthy process which serves to limit realistic sample sizes. SEMs use the complex interaction of an electronic beam with the surface of the object to produce a non-optical image (Ungar *et al*. 2003); it is necessary to define the SEM settings as images can vary considerably under different settings. Secondary electrons have to be used, as back-scattered electrons can produce total feature extinction when striations are at the same orientation as the detector (Pérez-Pérez *et al.* 2001). It is important to restrict the area under analysis as wear can vary between and within facets (Teaford 1994, 19); multiple samples from the chosen area should be captured and assessed for their representativeness. The relief of the tooth surface restricts high resolution recording to flat surfaces (Janis 1990, 247). The restricted area often leads to feature truncation, of striations in particular, limiting the value of this scale of quantification (Solounias & Semprebon 2002, 39).

There are two main approaches to removing the limitations outlined above. Solounias and Semprebon (2002) pioneered the use of light microscopy at a low resolution (x35), first for

microwear analysis, and later to include mesowear analysis. They argued that low magnification allows a larger surface area to be examined, so that atypical wear, which can distort the dietary signature, might be excluded. It is argued that loss of detail is not important, citing the feature truncation problems at higher resolutions; but has the advantage of allowing the inclusion of meso-level information (Semprebon *et al.* 2004; Solounias & Semprebon 2002). In addition, light microscopy methods process a large sample cheaply and quickly, essential for significant comparative data. However, image quality captured under light microscopy is poor. The use of a light stereomicroscope allows grey-scale images to be digitized at higher resolution (x120), with results consistent with previous analyses (Merceron *et al*. 2004a, b; 2005).

The second approach seeks to capture more accurately enhanced detail of individual wear features. Confocal microscopy has the advantage of producing true three-dimensional light images at high resolution (Ungar *et al.* 2003; Ungar & Scott 2007). The analysis of surface texture allows a far finer discrimination between features and allows the time resolution of feature formation to be studied, addressing interpretive limitations arising from overlapping features (Ungar *et al.* 2003). This method suffers from limited availability of the appropriate analytical equipment, and also the incompatibility of its data with large established ungulate databases based on SEM and light microscopy; however, it is easy to process a large sample quickly (Grine *et al.* 2002).

Having captured suitable toothwear images, the wear features are then recorded. In confocal methods, fully automated fractal analysis of digitally generated three-dimensional models produces repeatable characterisation of features (Ungar *et al.* 2003; Ungar & Scott 2007). Tests have shown that it is easy to train observers and that consequently inter-observer comparability is high (Solounias & Semprebon 2002), nevertheless there is some inter- and intra-observer error (Grine *et al.* 2002).

Dental microwear in SEM and light microscope images are both recorded semi-quantitatively (Semprebon *et al.* 2004; Solounias & Semprebon 2002). Ungar's (2002) image analysis software (Microware 4.0) uses Bitmap files of SEM images, and examines them at a fixed resolution of 148dpi (0.342μm per pixel). The software is a semi-automated image analysis procedure that is free and easily accessible on the internet. The recording of length, breadth and orientation of surface defects is easily semi-automated, but qualitative assessments of surface texture, generalised damage or polish to the enamel, and the temporal sequence clear in some palimpsests, are not readily quantifiable (Mainland 1998b, 1267).

The semi-automated measuring device is accurate, and clerical error has been removed by computerised data entry (Galbany *et al*. 2005, 26), however greyscale can vary greatly across an image, such that image-digitisation cannot easily isolate features or define their boundaries (Grine *et al.* 2002). Semi-automated methods of recording are reliant on recorder decision and precision, where each feature has to be identified, and its parameters accurately defined; there is considerable risk of observer error (Teaford 2007, 122).

Studies of inter- and intra-observer error found them to be 9% and 7% respectively, falling within common error margins (Grine *et al.* 2002). Whilst the number of counted features varied between observers, the proportions of different feature categories did not (Grine *et al*. 2002). Where sample sizes are small (Teaford 2007, 122), or where fine inter-dietary patterning is being investigated, error can be greatly reduced if there is only one recorder (Grine *et al.* 2002; Vanpoucke *et al.* 2009, 142). However the comparative ungulate databases have been generated by a number of recorders, using a range of image magnifications; a 19% error is attributed to different magnifications (Grine *et al.* 2002). Although Galbany *et al.* (2005) argue that inter- and intra-observer variability is such that only fully automated recording should be used, there are considerable advantages to generating data compatible with published ungulate databases.

The array of unknown factors and potential combinations of wear associated with different diets necessitates standardised categories of quantification. The categorisation of microwear defects was first established by Solounias and Hayek (1993). The continuous method counts total features with no separation. The dichotomous method, based on the minor to major axis ratio, identifies two features, where striations have a ratio of <1:4 and pits >1:4. The polychotomous method categorises further features. For example, Solounias and Semprebon (2002) categorise large pits with a diameter of ±15μm and small pits <15μm; narrow striations with a breadth of ±15μm, and wide striations <15μm.

In the preliminary data assessment by simple descriptive statistics, both continuous counts and dichotomous pit to striation ratios are generally considered the most useful. Striation breadth is a useful discriminant in extinct ungulate diet studies (Solounias & Hayek 1993, 437). Striation length, often truncated, offers little information (Solounias & Sembrebon 2002, 39). In their study on the seasonality of roe deer feeding niches, Merceron *et al.* (2004a, 129–130) find pit size and striation width to be useful. In identifying domestic caprine foddering, pit shape and striation width are useful discriminants (Mainland 2001, 84).

Multivariate statistics are used to identify more specific relationships, particularly relevant for DMA where each diet is usually represented by several variables (Mainland 1997, 214). Correspondence analysis and discriminant analysis are used to manage the data, and present it visually, so that groupings and variations emerge in relationship to each other (Mainland 1997, 215). Where there are small sample sizes, however, the possibility increases of groupings being due to chance alone. Stepwise discriminant analysis can identify the minimum number of variables required to give good inter-group separation, thus minimising the impact of small sample size (Mainland 1997).

Dental microwear analysis has led to the establishment of large comparative databases based

on dietary preferences in ungulates. Mainland (all references) has built a database of *c.* 400 modern domestic sheep from northern Europe and Greece. It has been used to approach archaeological research questions by Mainland (1998b, 2000, 2001, 2003); Mainland and Halstead (2002); Beuls (2004); Beuls *et al.* (2000a, 2000b, 2002) and Rivals and Deniaux (2003, 2005). A large ungulate database constructed from both SEM and light microscopy data now includes 890 individuals and 50 species (Semprebon *et al.* 2004; Solounias & Semprebon 2002) and has been used in palaeontological research by Billet *et al.* (2009), Merceron *et al.* (2004a, b, 2005, 2006), Rivals and Semprebon (2006), Semprebon *et al.* (2004), Solounias and Hayek (1993), Solounias and Moelleken (1992), and Solounias and Semprebon (2002).

There is enough consistency in microwear patterning across mammalian orders to allow dietary signatures in a wide range of species to be used (Merceron *et al.* 2005, 174; Wilkie *et al.* 2007, 246), and it appears that feed type, rather than geography, determines microwear (Mainland 1998b, 1264).

8.6. Archaeological limitations to the application of DMA

There are further limitations arising from the use of archaeological data. Where the soil, hydrology, and seasonal vegetation in the palaeoenvironment are insecurely understood, the equifinalities posed by pit formation and by the unresolved cause of microwear limits the ability to directly associate microwear signatures with dietary regimes in domestic sheep.

Soft herbaceous forbs, young grass shoots, clean leafy browse, field weeds, arable legume by-products and grain-rich fodder might have similar microwear signatures of pitting but no striations. Whereas mature grasses, reeds, stubble, and chaff or hay fodder might have striation microwear. Unknown pasture conditions, either muddy or dusty, and unknown fodder collection and storage methods might alter the numbers of both pits and striations.

These more subtle differences in domesticate diets, including seasonal feeding regimes, are more complicated to interpret.

Microwear is only caused by certain ingested material, with other food types leaving no effect at all on enamel. Consequently an understanding of archaeological sheep diet is dependent on uniformitarian assumptions (Teaford 2007, 120). These assumptions might include the feeding behaviour of sheep, herding practices relating to pasturing and foddering, and the range of likely niches in the palaeoenvironment. Uniformitarian assumptions might lead to overlooking foodstuffs outside modern experience, which could have contributed to wear (Teaford 2007, 123).

Teeth survive well in the archaeological record and those that are abraded may be easily recognised and rejected. Microwear associated with food is clustered at certain points on enamel facets and is clearly separable from the randomly positioned, non-orientated marks associated with taphonomic processes (Teaford 2007, 107).

Sheep and goats have different feeding habits that introduce a further set of variables into the analysis and interpretation of the archaeological dataset. There are differences in the enamel prism pattern of sheep and goats (Grine *et al.* 1987) and in their tendency to become polished or abraded (Beuls *et al.* 2002, 342). Little research has been undertaken on the non-dietary effects of sex on tooth microwear; in any case, the sex of archaeological sheep jaws cannot be assessed. Microwear size and quantity varies between tooth types, although occluding teeth in upper and lower jaws have the same wear patterns. Microwear shows little variability due to the age of teeth, providing they are neither so young that they are barely in wear, nor so old that occlusion is lost. Dental microwear analysis of archaeological teeth is dependent on the reliability of zooarchaeological methods of sheep and goat separation, tooth-type identification, and tooth-age stage.

8.7. Summary

Mouth action operates on ingested materials according to the abrasiveness of the ingested matter, and results in microwear that is diagnostic of the general dietary regime in the weeks before death. Microwear stems from individual ingestion events and can be related, via mesowear, to the long-term dietary regime of the animal. Diet, seasonality, feeding niche and husbandry practices have been successfully investigated through dental microwear analysis.

Limitations have been identified. In particular, variability arising from species-related enamel formation, tooth-type, age and sex should be controlled, and quantitative biases arising from semi-objective recording techniques by different recorders should be assessed.

The agent of microwear is still not fully resolved, causing equifinality difficulties in dietary interpretation. The ability of the two likely agents, phytoliths and grit, to scratch enamel has been questioned. Tooth hypsodonty in ungulate evolution might have been retained to manage grit ingestion rather than co-evolving with phytolith-rich grasslands.

Grit incorporated into the food has been shown to produce pits in dusty browse, and its effects can be differentiated from pitting caused by tough woody browse, fruit or seeds. High amounts of grit have also been shown, by dung analysis, to be associated with striations in sheep grazing on poor pastures in north Europe and Greece. In savannah ungulates, the phytolith richness of different grasses has been shown to correlate to striation widths in associated microwear. However it is likely that the amount of wind-blown grit in different grass niches would lead to the same correlation.

The usual analytical method matches archaeological and palaeontological dental microwear to that associated with known diets; the use of large databases is shown to be effective,

producing largely consistent results. An alternative, or additional, approach is the construction of a modern comparator relevant to the research, where the associated ingested food material and dung are collected along with the dental microwear. This approach not only adds relevant dietary signatures to the published database, but also identifies the role played by phytoliths and grit so that more subtle dietary discrimination can be effected. Building on Mainland's (2003) convincing link between ingested grit and striation formation in north Europe, this research tests that premise in an Anatolian context, more relevant to the Çatalhöyük palaeoenvironment.

8.8. Modelling the contribution of dental-microwear analysis

In summary (*Table 8.1*), dental microwear analysis of archaeological sheep teeth provides a methodology that might contribute useful information on pre-historic herding practices. A model of the use of dental microwear analysis in interpretation of dietary regimes in Çatalhöyük sheep is presented below (*Table 8.2*). Additional evidence from a modern compartator will be added, and used to remove many of the equifinalities.

- Archaeological teeth from Çatalhöyük survive well in the record and are easily assessed for taphonomic alteration.
- Zooarchaeological methods can identify teeth by species, type and age, so that non-diet related microwear may be controlled.
- Zooarchaeological determination of age-stages in teeth can identify samples from young animals that might, in Çatalhöyük meat herds, be male or female, and from older animals more likely to be female.
- Dental microwear from a representative area of a certain wear facet on a named tooth when examined under SEM, using secondary electrons at defined settings, will give consistent images.
- Ungar's (2002) image analysis software semi-quantitatively records the microwear and, when used by one recorder, may be assessed for observer error.
- Published databases of ungulate diets and of domestic caprine feeding regimes may be used as comparators using simple descriptive statistics. Where published databases use a different tooth, only simple statistical comparisons of non-metric aspects of the features may be attempted.
- Broad dietary descriptions of young-and-clean versus old-and-dirty feed may be identified using published databases.
- The published databases may not be used for more complex dietary comparisons due to differences in image magnification and the recorder.
- A modern comparator from local herds can compare feed, dung and microwear to determine the role of phytoliths and grit in feature production.
- A modern comparator can allow finer analysis of diets that distinguish seasonal feeding on grasses, cereals and browse.
- Dental microwear records the dietary regime in the last few weeks before death, and in archaeological samples interpreted as food waste, the diet might be designed to fatten up animals awaiting slaughter.

Table 8.1
Summary of the contribution that dental microwear analysis might make to elucidating herding practices at Çatalhöyük

Plant group		*Pits*		*Striations*			
				If caused by phytoliths		*If caused by ingested soil*	
		Small round	Large irregular	Narrow	Broad	Narrow	Broad
Monocotyledonous	Young grass	X					
	Mature C3 grasses			X		X	
	Mature C4 grasses				X		X
	Hay fodder			X		X	
	Cereal stubble			X		X	
	Cereal fodder			X		X	
	Reeds			X		X	
Dicotyledonous	Young pasture forbs	X					
	Field edge weeds	X					
	Fallow crops	X					
	Legume straw	X					
	Weed fodder	X					
	Leafy browse		X				
		Increasing with more ingested soil		Increasing with maturity of plant		Increasing with more ingested soil	

Table 8.2
A preliminary model of the use of dental microwear in the interpretation of dietary regimes in archaeological sheep before death

CHAPTER 9. RESEARCH DESIGN AND ISSUES OF SAMPLE SELECTION

Having discussed the methodologies used in this research, it is finally possible to construct a research design that may usefully approach a series of questions to be asked of the archaeological data. *Section 9.1* describes the selection of modern material that is used, by analogy, to interpret the archaeological data, and *Section 9.2* considers the choice of archaeological materials and includes the sampling strategy that will provide robust chronological and spatial data.

In this research, oxygen isotope and dental microwear analyses of sheep tooth enamel are the methods chosen to elucidate details of Çatalhöyük herding practices. Their datasets are modelled to give information on birth season, first year movement and diet before death (*Figure 7.15* and *Table 8.2*). The scheduled management of breeding, fallowing and slaughtering is then approached within models of the feeding resources for sheep herds in the Çatalhöyük environment (*Figure 6.4)* and sheep breeding, movement and feeding behaviour (*Tables 6.2 & 6.4*).

It is possible to ask whether Çatalhöyük herders, at specific times during the Neolithic occupation, or from specific neighbourhoods or buildings in the settlement:

- added new stock, brought in from other settlements;
- controlled or manipulated the lambing season;
- took fallow herds (juveniles and barren females) to seasonal pastures away from the settlement hinterland;
- had ample pastureland near the settlement;
- had access to arable stubble or by-product fodder;

- had seasonal slaughtering practices.

The chapter concludes, in *Section 9.3,* with a preliminary assessment, common to both datasets, of the collected samples, and leads to adjustments in the research design. In *Chapters 10 and 11* the results and analyses of, respectively, the oxygen isotope and dental microwear datasets are discussed, followed by interpretation in *Chapter 12*.

9.1. Selection of modern material

The methodology chapters (*Chapters7 & 8*) described how archaeological datasets might be understood by analogy to data patterning in fully documented modern material. This section introduces the modern datasets that are presented in this thesis, and describes the objectives underlying their choice. Published comparanda and research-relevant local baseline material are used for both datasets, and are integrated in order to model the archaeological evidence.

9.1.1. Published databases

The use of published databases has the following objectives:

- oxygen isotope data relevant to the Konya Plain provide monthly meteoric $\delta^{18}O$ values, the annual mean, range, maximum and minimum values, and a baseline of inter-annual variability;
- dental microwear data provide dietary-related microwear in a range of ungulate diets and in seasonal feeding regimes of domestic sheep.

9.1.1.1. Oxygen isotope databases

The Global Natural Isotopes in Precipitation (GNIP) database is published by the International Atomic Energy Agency (IAEA/WMO 2006), and provides worldwide records of monthly oxygen isotope values for 40 years (June 1963 to December 2004). The Ankara station (WMO1713000), at 39.95° latitude, 32.88° longitude, and 902m elevation, provides the nearest, and most relevant, comparator. Ankara is 150km northeast of Çatalhöyük and

100m lower in altitude; the weather trajectories are broadly the same. Complete annual records can be used to model inter-annual variation. GNIP has also integrated data from its collecting stations to generate maps showing the monthly distribution and change in isotopic values across southwest Asia (IAEA 2001).

9.1.1.2. Dental microwear databases

The published databases of modern dietary-related microwear in ungulates and domestic caprines were discussed in *Chapter 8*, as an understanding of their application and limitations is integral to the methodology. Selected datasets from Mainland (1998b); Rivals and Deniaux (2003, 2005); Solounias *et al.* (2000) are suitable for use in simple statistical comparison to the archaeological datasets.

9.1.2. Modern comparator

In constructing a modern baseline, selection criteria seek to remove equifinalities in interpretation, and to explore uniformitarian assumptions. The establishment of a modern comparator in this research has the following objectives:

- to reduce the variables associated with climate, habitat and taxa by the use of local, traditionally-reared sheep, that might be expected to have been raised in somewhat similar environments to archaeological sheep from Çatalhöyük;
- to interpret oxygen isotope and dental microwear signatures in sheep teeth, in reference to underlying environmental conditions, and through analyses of associated food, water and dung;
- to provide specimens from sheep born in different months;
- to provide specimens from sheep that consumed a range of seasonal diets before death;
- to provide specimens of seasonal water, and of food and dung before death.

9.1.2.1. Selection of modern comparator

Three locations were selected as best meeting the criteria outlined above, and one sheep

breed, Karakol, was chosen for selection. Specimens from a sheep herd from the village of Küçükköy were chosen as the sheep are raised only two kilometres from Çatalhöyük, and all herd movement is at the Konya Plain altitude. Pastures are sited on alluvium, some of which is the lower alluvium formed during the Neolithic (Matthews *et al.* 2000, 180). *Table 9.1* summarises salient parts of interviews with the farmer.

Lambs are born in March; they start grazing at 15 days, and are progressively weaned from 5th May (The day of Hidrellez) until completion on 10th July. Lambs are pastured on 'daily pasture' near the village until they are weaned. Daily pasture at this time of year includes young forbs and new grass growth from field and stream edges or, during April, soft shoots of tillered crops. At night they return to the byre where they are not fed, except by suckling. In mid-July, lambs, join fallow herds and are droved to dedicated 'distant pastures', c. 5km from the village and at the same altitude. They remain away from the village with shepherds until 25th October. Until August, the fallow herds feed on unimproved pastures of maturing grasses, and avoid spiky, aromatic mature forbs. They rely on the water content of their pasture grasses until late June, but in later arid months they nibble on fresh, green canal-edge reeds and rushes and are given canal water sourced from a large reservoir (Apa Baraji) c. 50km upstream on the Çarşamba River. From July until October, fallow herds are moved onto cereal stubble and remains from harvested beet and legume crops. From 25th October until 20th March the daily pasture is used from 4am to 6pm, unless hard frost or deep snow restricts herds to the byre. Daily pastures have the same vegetation as distant pastures. Herds are never fed at night in the byre. If bad weather keeps herds in during the day, they are given hay, or fodder made from the farm's own arable by-products. Finely chopped bean straw (al saman) or wheat straw (ak saman) is mixed with feed made from lentil, beet, bean, watermelon and beet residues. (Mevlut Sivaş, the farmer, on 19th July, 2007, a week later on 26th July with his shepherd, and with follow-up interviews in July 2008 and 2009)

Table 9.1
Summary of interviews about Küçükköy sheep herding

Kızılkaya is the village in which the Early Neolithic site of Aşıklı Höyük is situated, 150km northeast of Çatalhöyük, in Cappadocia. Specimens were chosen from here as traditional herding takes place in a very different topographical and hydrological setting. It is also interesting to compare data from near Çatalhöyük with that from near an antecedent settlement that shares many material culture aspects. *Table 9.2* sums up relevant information from interviews.

Lambs are born in mid-March and begin nibbling grass at one week. Weaning begins in mid-April and is complete by 21st June (Günüdönümü). During this time, to facilitate milking, lambs and nursing ewes are grazed in breeding herds on field edge grasses and forbs; they are not used to tiller new crops. After 21st June shepherds graze the lambs, in fallow herds, slightly further from the settlement at the same altitude. They remain outside overnight until November, but at times make use of a sheepfold (ağıl) on the edge of the village. Sheep in fallow herds graze on unimproved pastures in the deeply shaded valley of the perennial River Melendiz, where grasses and forbs remain green until the end of June. Sheep choose to eat young grass, clover and chicory. Each year, half the arable fields are fallow, and fallowed sheep are put to graze on field weeds. Before mechanisation, stubble in newly harvested fields was grazed by fallow herds between July and October.
In bad winter weather, sheep are kept inside the byre (mandıra) near the farmhouse, but prefer to be outside grazing on mature grasses, spurge, wild peony leaves and tamarisk fronds, even if they are muddy. In the byre, sheep are foddered on green straw from legumes, but never on old, coarse cereal straw. Clover is grown as sheep fodder and added to beet residue and finely chopped cereal and legume chaff. Sheep are never given reeds or rushes, but emergency foddering includes leaves of apple, pear and apricot trees. Sheep can drink whenever they wish from the river, occasionally they have tap water in winter, sourced from the nearby Ilhara River.
(The farmer, Naci Kayan; the village headman (mukhtar); and their shepherds in July 2007 and 2008, and from Ertuğ-Yaraş' 1997 ethnographic study)

Table 9.2
Summary of interviews about Kızılkaya sheep herding

The Bozdağ Wild Sheep Reserve holds a remnant population of wild sheep, *Ovis orientalis*, and is managed by the Ministry of the Environment and Forestry (İl Çevre ve Orman Müdürlüğü). The sheep were chosen to model natural grazing at higher, exposed altitudes and, in addition, it is likely that they more closely resemble Neolithic domestic sheep than do modern domestic breeds.

The reserve is 30km from Çatalhöyük in eroded, treeless hills that rise 1735masl. The average summer temperature is 21.3 °C; this is 9 °C lower than at Çatalhöyük, down on the plain. The reserve is restricted to a steppic area, where sheep supplement their grass-rich diet with *Onobrychis vicifolia*, a nutritious and palatable legume. As sheep no longer have access to lower oak parkland, their graze is supplemented with commercial pellets in winter. There are no springs in the reserve, and so water pumped from aquifers is provided in summer. Lambs are born in May and move with their mothers uphill as summer progresses, following green pasture, and not returning to lower levels until the rutting season in late autumn. (Kaya 1990; 1991; Kaya & Aksoylar 1992; Kaya et al. 2001; Kaya et al. 2004). And interviews with the Reserve's vet, Dr. M. Çelik, and with Dr. M.A. Kaya, Head of Biology, Education Department, Selcuk University in July 2007 and 2008.

Table 9.3
Summary of information and interviews about Bozdağ wild sheep

The three locations allow seasonal water sources associated with the Çarşamba alluvial fan, nearby hilly uplands, and a deeply shaded perennial stream to be modelled; however, interpretation has to take account of the occasional use of non-seasonal drinking water in Küçükköy and Bozdağ herds. Birth season and herd movement history allows different herding regimes to be modelled from tooth enamel oxygen isotope data.

In each location, the seasonality of pasturing and foddering is clearly associated with different diets; the grazing diets are all relevant to this research but the fodder diets in winter

are less useful as they consist of pellets or contain various plant residues. The soil–phytolith composition of seasonal diets and associated dung allows dental microwear signatures in pre-slaughter dietary regimes to be modelled.

9.2. Selection of archaeological material

Çatalhöyük has been selected as the archaeological case study in this thesis because of its:

- chronological and spatial location in the Neolithic of southwest Asia;
- palaeoenvironmental setting;
- long 1200 year settlement;
- economic dependence on domestic sheep products;
- exploitation of domestic cereals and legumes;
- large zooarchaeological assemblage.

9.2.1. Zooarchaeological assemblage

In order to understand how the selected specimens relate to the original population being sampled it is necessary to understand the processes that cause information loss and likely biases (Klein &Cruz-Uribe 1984, 3). The animal bone entering the archaeological record is unlikely to reflect the proportions of the living local faunal population. Domestic herds are usually split into different parts, depending on their perceived value and on the immediacy of their economic contribution, such that only those dying near the settlement are likely to enter the death assemblage. Zooarchaeological analysis of the Çatalhöyük assemblage (*Chapter 4*) suggests that only the cohort targeted for slaughter entered the zooarchaeological assemblage.

Bone that is less robust, often from young animals, survives less well after deposition, as it is vulnerable to attritional processes such as abrasion, weathering and scavenging. The large, undisturbed middens at Catalhouk favour bone preservation (*Figure 9.1*), and are clearly recorded in the Çatalhöyük Excavation Database Unit records (www.catalhoyuk.com) and in the Faunal Database Faunal Unit Descriptions (FUD) (www.catalhoyuk.com).

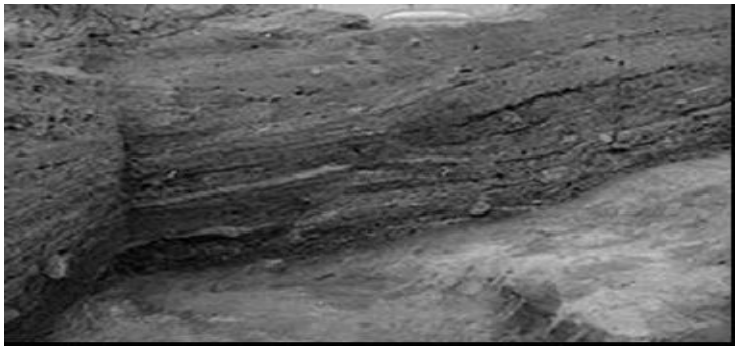


Figure 9.1
Photograph of a section of a typical Çatalhöyük midden

Research questions determine the excavation strategy and the zooarchaeology recording priorities. At Çatalhöyük, the published zooarchaeological assemblage focused on units that had been given priority in the first five years of excavation: <10% of possible contexts were selected (Hodder *et al.* 2007). Retrieval methods might introduce bias in the zooarchaeological specimens entering the archaeological assemblage but, at Çatalhöyük, the material excavated from each unit has been handpicked and dry-sieved through a 5mm mesh; in addition a ≤30l fraction of each unit has been wet-sieved (Hodder *et al.* 2007).

9.2.2. Sample data analysis

The methodological requirements of data analysis also dictate sample selection, and introduce further bias (*Chapters 7 & 8*). Both methodologies take evidence from cheek tooth enamel, but inter- and intra-species variation in morphology, physiology and behaviour may mask environmental or anthropogenic influences, so a strategy of targeted sample selection is used to constrain the variables, as discussed in the following sections.

9.2.2.1. Selection by species, sex and age

Behavioural differences between sheep and goats are manifested in dental microwear (Mainland 1998b) and oxygen isotope signatures (Delgado Huertas *et al.* 1995); restricting the dataset to one species is an effective strategy that removes inter-species variation. At Çatalhöyük, sheep were selected as they dominate the caprine zooarchaeological

assemblage; they were separated from goats using a combination of Payne's (1985) criteria for deciduous fourth pre-molars, and Halstead *et al.*'s (2002) criteria for separating pre-molars and the third molar (Russell & Martin 2005, 65).

It is not possible to assign sex to archaeological sheep jaws, and therefore any sex-related biological differences cannot be established in either dataset. Dental microwear shows very little variation due to age, except in very old and very young animals (Beuls *et al.* 2002) and the effects of age on oxygen isotope signals have not been investigated. At Çatalhöyük, tooth eruption patterns and the degree of tooth wear in the mandibular tooth row (Payne 1973) are used to establish the sheep's stage of development.

9.2.2.2. Selection by tooth type

Both methodological approaches demand that a known tooth type is used to allow the best use of the published comparative databases. Oxygen isotope signatures differ in each tooth because enamel formation follows a chronological sequence (Moss-Selentijn *et al.* 1997), and dental microwear features, in sheep and goat, vary in size between tooth types (Mainland 1998b).

Mandibular teeth have the advantage of being diagnostic of sheep and goats, and of giving more age information, when part of a tooth-row in the jaw. The third mandibular molar is preferred for oxygen isotope analysis because of its long temporal sequence, but has not been used in published dental microwear analysis. The deciduous fourth pre-molar is not suitable for oxygen isotope analysis as it is small and partially formed *in utero* (Suga 1982; Weinreb & Sharav 1964, 898); however it is the basis of Mainland's caprine dental microwear database. The second mandibular molar is used in oxygen isotope analysis as it provides an annual cycle of isotope data corresponding to the first year of life. In addition, dental microwear in this tooth may be compared to that in the second maxillary molar which is widely used in published ungulate databases; the teeth are in occlusion and exhibit the

same dental microwear (Teaford & Walker 1984, 194). The second mandibular molar is the preferred choice in this research as few sheep lived long enough for full third molar eruption (Russell & Martin 2005). This choice, unfortunately, means that comparison to Mainland's database is considerably restricted.

The two methodologies used in this research use different sampling areas on the teeth. Dental microwear analysis uses a section of the infundibular enamel band and oxygen isotope analysis demands a certain height of tooth column for an adequate sampling sequence. Both older and younger molars lack a good infundibular band, and older teeth are often too short to provide an effective tooth column length. It is possible to identify sheep second mandibular molars provided they are within a nearly complete tooth-row (*Figure 9.2*). Teeth with complete mesial infundibular bands in wear are coded 11–17 in the Çatalhöyük Faunal Database. The mandibular tooth-row is easily assigned a side so that the possibility of two mandibles coming from one animal can be clarified.

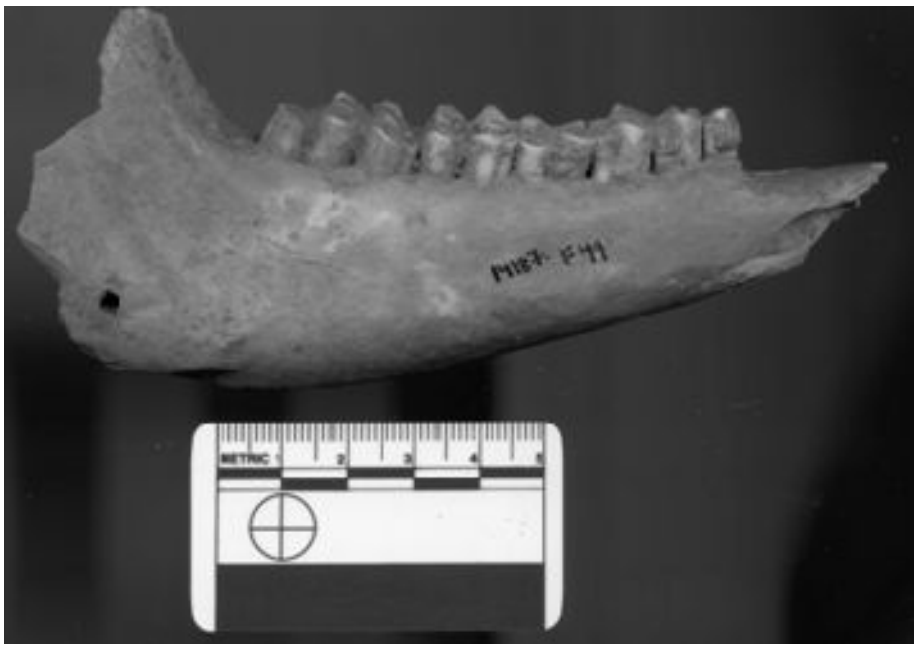


Figure 9.2
Photograph of a typical Çatalhöyük domestic sheep mandible used in this research

9.2.3. Sample interpretation

The evidence is used to investigate temporal and spatial patterning in different groupings of the data, in addition to describing and exploring variety. The sampling strategy selected specimens from the most informative contexts, aiming for a high degree of contextual security and for a significant sample size.

At Çatalhöyük, deposits can rarely be considered *in situ*, and are likely to be secondary depositions with inexact temporal and spatial resolution. The best indicators of undisturbed depositional contexts are described in the Çatalhöyük Excavation Database Unit records (www.catalhoyuk.com) as inter-digitated and finely layered unit beddings with ashy lenses, characteristic of undisturbed midden (*Figure 9.1*). Undisturbed midden might be expected to have bone inclusions that are still in articulation with little sign of weathering, abrasion or gnawing: as described in the Faunal Unit Descriptions (www.catalhoyuk.com).

There are a various short-comings to the current phasing system. Buildings do not provide precise stratigraphic relationships to horizontally adjacent buildings, introducing some temporal slippage in each level. The subtlety of typological change at Çatalhöyük, and the absence of occupation hiatuses, adds to the insecurity of umbrella phasing across all areas. Yet the use of typologies is important because different areas of the mound were occupied at different times. Recent work re-evaluates Mellaart's Level system, and has found further areas of weakness. The overlap used by Mellaart to link Levels IV and V horizons was dependent on a partially excavated midden with an unresolved stratigraphic relationship to abutting buildings. Furthermore, new height measurements suggest that Levels VIA and VIB need not be phased separately. The re-evaluation has given rise to textual comment in the excavation Unit reports stating that some buildings in the South–TP Areas should, on reflection, be assigned to later Levels. In the South Area, Mellaart Levels VI to III might more accurately be assigned V to I.

Table 9.4
Summary of Farid's (2008) review of the Çatalhöyük phasing system

It is difficult to determine the precise phasing of middens as they are external to buildings, and their relationship to them is unclear. Nevertheless, Çatalhöyük middens are the repository of most animal bone, and provide the greatest contextual security. The Çatalhöyük phasing system (*Figure 3.3*) is currently under review (*Table 9.4*).

Method	*Type of analysis*	*Sample size*	*Sample type*	*Citation*
Oxygen isotope analysis	Pilot	8	Individual	Wiedmann *et al.* (1999)
		1	Chronological phase	Tornero & Saña i Seguí (2008)
	Modern comparator	13	Caprine group	Mashkour *et al.* (2002)
		5-8		Balasse *et al.* (2002); Balasse & Tresset (2002, 2007)
	Illustrative	1	Chronological period	Sharma *et al.* (2004); Bocherens *et al.* (2001)
	Statistically tested	1-8	Species group	Lösch *et al.* (2006)
		1-13		Richards *et al.* (2003)
		10	Chronological phase	Pearson *et al.* (2007)
	Testing bimodality	35	Individual	Balasse & Ambrose (2005)
Dental microwear analysis	Statistically tested	1-2	Species group	Ungar, cited by Rivals & Deniaux (2005)
		40-60		Beuls *et al.* (2002)
		4-40		Solounias & Moelleken (1992)
		5-21		Semprebon *et al.* (2004)
		6-128		Merceron *et al.* (2005)
		11-16	Caprine diets	Mainland 2000)
		11-30		Mainland 2001)
		8		Mainland & Halstead (2002)

Table 9.5
Summary of sample sizes used in relevant published research

A review of past practices provides guidance or, at least, precedence on sample size strategy (*Table 9.5*). The size of the sample used in both datasets varies from researcher to researcher and is often a function of what is available rather than adhering to any principle. In both methodologies it is the tooth itself that is being sampled: for a series of enamel bands in

oxygen isotope analysis, and for individual enamel defects in dental microwear analysis. In addition, each sample in oxygen isotope analysis is sub-sampled for multiple mass spectrometry readings. Intra-tooth sampling contributes to the robustness of the datasets.

9.3. Sample selection: preliminary evaluation and adjustments

9.3.1. Selected modern specimens

The sampling strategy for the modern baseline was to collect two tooth specimens per season (eight, in total) from each location, three specimens each of different seasonal food and fodder, and histories of all sampled animals. Sheep were not deliberately slaughtered for this research, and the proposed number of specimens was not reached through natural deaths, consequently the seasonal distribution of deaths was uneven (*Appendix 8*).

Plant species and parts	*Vegetation summary*	*Collection season*	*Number of samples*
Wheat & barley stubble	Cereal stubble	August	3
Barley straw fodder	Barley straw	Winter	3
Legume straw fodder	Legume straw	Winter	3
Dry grass hay and dry annual forbs, mainly wild legume species	Late summer pasture	August	3
Wheat straw fodder	Wheat straw	Winter	3
Green pasture grass shoots & new green growth of annuals such as clover, chicory	Spring pasture	June	6
Green pasture grass shoots	Spring grass	April	3

Table 9.6
Summary of modern plant collection

The food that was ingested leading up to deaths was determined, and appropriate plant collections were made (*Table 9.6*). Water collection was not consistently carried out, so the few analysed samples did not allow patterns to emerge and have not been included. Dung samples associated with feeding at death were collected, but a laboratory accident resulted in their being of no value.

Specimen	*Altitude*	*Brief description of environment*	*Month of birth*	*Water intake*
101 102 103 105 106	1020m a.s.l.	Degraded pastures on alluvial plain	March	Wet grass mainly, green reeds by irrigation canals in summer, tap water in stables rarely. Canal and tapped water from Apa Baraj reservoir
201 202 203	1120m a.s.l.	Water meadows in perennial stream gorge	March	Spring -pasture plants, Summer/Autumn -Melendiz river, winter stabling -tapped from Ilhara river
301 302	1860 m a.s.l.	Exposed hillsides	May/June	Wet grass mainly + local small seasonal springs

Table 9.7
Summary of water ingestion history of modern specimens

Permission to use the Bozdağ material was granted by the Turkish Ministry of Foreign Affairs (Türkiye Cumhuriyet Dışısleri Bakanlığı), provided analysis was carried out in Turkish laboratories. Unfortunately, this was not possible because NERC funding requires the use of its own laboratory facilities. Regrettably, it was only possible to use the collected food material but not the sheep teeth; however Selcuk University gave permission for dental microwear analysis of the specimens in their reference collection.

In order to provide an altitude signature, alternative arrangements were made to analyse two teeth from sheep that were raised *c.* 1860masl, but *c.* 1000km from Çatalhöyük. The sheep give birth in late May–early June. In summer they were grazed on surrounding hillslopes, and over winter they were close to the settlement, confined to byres much of the time. Water requirements were met by water on leaf surfaces and leaf-water. The sampled sheep were killed in late July or early August after grazing on natural pasture. *Table 9.7* summarises water ingestion history of all modern sheep specimens.

9.3.2. Selected archaeological specimens

Çatalhöyük faunal team leaders accepted an initial pilot study (Henton *et al.* 2010), produced to satisfy requirements on destructive sampling (Russell *et al.* 2008), and allowed full access to the archived sheep mandibles. Tooth specimens were collected and exported over three years; sampling was from all context types initially, but later restricted to undisturbed middens. It is not unexpected that the identifiable sheep elements should constitute such a small percentage of the highly fragmented caprine-sized assemblage and, given the restraints imposed by the methodological criteria, the low number of suitable specimens is likely to be accurate; the strategy effectively became one of taking all specimens that were suitable (*Table 9.8*). In each unit, no two molars come from the same animal and so the sample number of teeth represents the sample number of sheep. In total 81 were exported and 72 teeth were selected for analysis (*Appendix 9*).

Sample population up until 2007	*Sample number*	*% of population*
Number of recorded fragments	896,845	
Caprine-sized NISP	697,615	
Sheep NISP	5,220	0.75% of caprine- size NISP
Sheep mandibles with teeth	277	5.3% of sheep NISP
Sheep mandibles with M_2 in suitable wear	81	29.2% of sheep mandibles with teeth
Undamaged sheep M_2 for microwear	72	
Undamaged sheep M_2 for isotopes	58	

Table 9.8
Table showing percentage of Çatalhöyük sampling populations that were suitable for oxygen isotope and dental microwear analysis

The age distribution of the sampled teeth (*Figure 9.3*) does not fully reflect that of the retrieved assemblage, as the sampling strategy suitable for both methodologies resulted in a marked bias towards older animals, (*Figure 9.4)*. There are no specimens under one year old and 32 are over 4 years old. The other 40 specimens fell within the cull age between 1–2 and 3–4 years old, but only 8 specimens were from sheep that died at the maximum culling age of one–two years old. As a result, the sample is skewed, truncating information from the maximum cull-age cohort. The implications of this are discussed in *Chapter 12*.

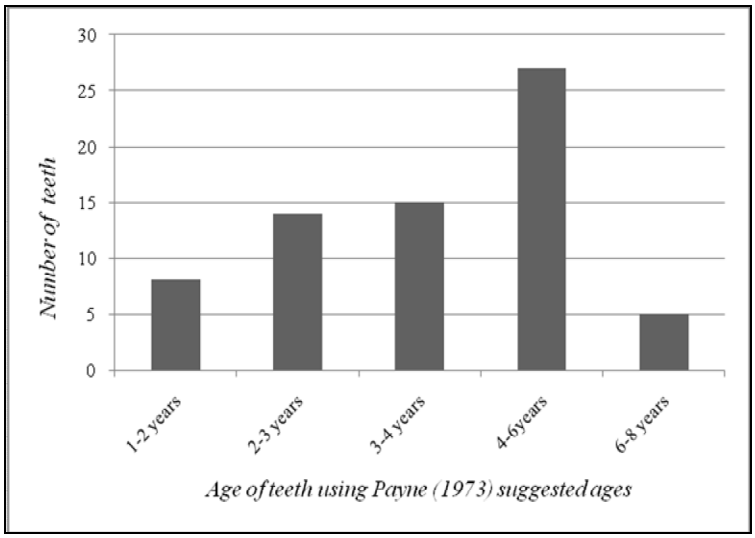
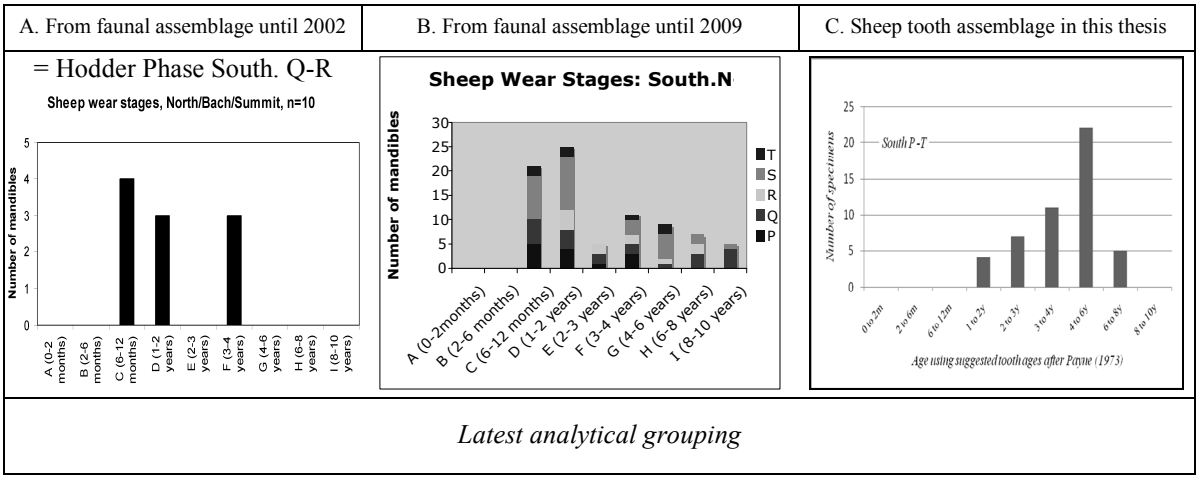
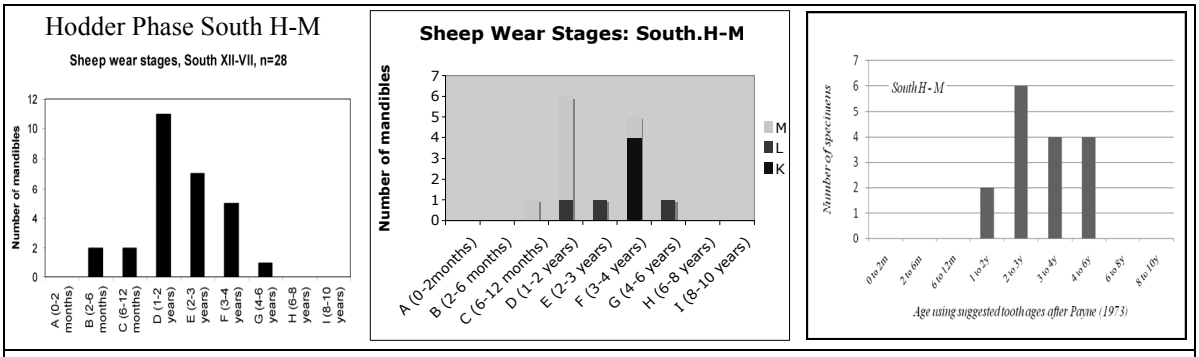


Figure 9.3
Distribution by tooth-stage ages in all archaeological specimens

A summary of information (*Appendix10*), taken from the excavation and faunal unit description databases, was used to assess the degree of contextual security, asking if the sheep mandible specimens are likely to belong to an assigned phase. Confidence was scored from three stars (high) to one (low). All specimens are from Neolithic contexts and most are from undisturbed middens or other contexts where re-working is minimal. Subsequent building events establish clear *termini ante quem* for the few specimens taken from re-deposited layers. In spatial and chronological analysis and interpretation, the evidence from the latter specimens is explicitly scrutinised.





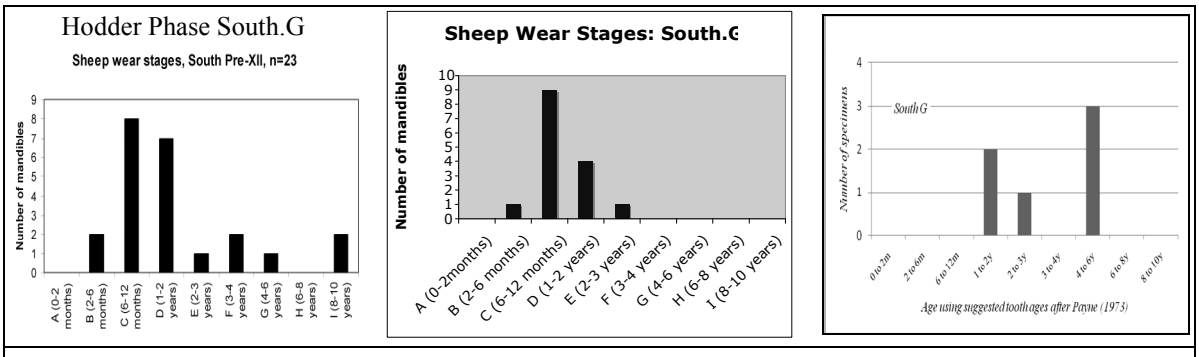


Figure 9.4
Figures comparing distribution of tooth wear stages in the thesis assemblage (C) and zooarchaeological assemblages based on the 3 analytical groupings used in (A) Russell & Martin 2005, 71, and (B) Twiss et al. *(2010, 9)*

The specimens were placed within the on-going re-evaluation of the Çatalhöyük stratigraphy, phasing and chronology (*Appendix 11)*. The chronology used in this thesis, is constructed as follows:

- Mellaart Levels XIIA to I (re-labelled South G to South T in 2008) provided the chronological spine in the South and TP Areas.
- Where specimens were taken from South units with inconsistent phasing, they have been ascribed the later phases as suggested in the textual comments.
- Where specimens were taken from other areas, they have been given likely phasing correlations based on typography (S. Farid, *pers. comm.,* 9th December, 2009).
- These three strands, establishing the overall chronology, are highlighted in grey in *Appendix 11*.

Analytical groupings used in thesis	*Excavation levels and areas*	*Dating*		*Oxygen Isotopes*		*Dental microwear*	
		Approximate dating	Approximate duration	All specimens	Most secure specimens	All specimens	Most secure specimens
6	South T & TP	6250 -6100?	150?	11	6	12	7
5	South R & S	6375-6225?	150	8	8	13	13
4	4040 & IST	6400?-6225?	175?	11	11	14	13
3	South P & Q	6350-6200?	150?	9	7	11	9
-	South N & O	6475-6375	100	*No data*			
2	South M & Bach	6625-6500	125	8	6	10	6
1	South G, K, L & KOPAL	7325-6525	800	11	10	12	11
			Totals	***58***	***48***	***72***	***59***
Area groups	South Areas 44		Other Areas 28				
Building types	Long-lived building 20		Other buildings 17				

Table 9.9
Table showing sample sizes by chronological and spatial groupings of archaeological specimens

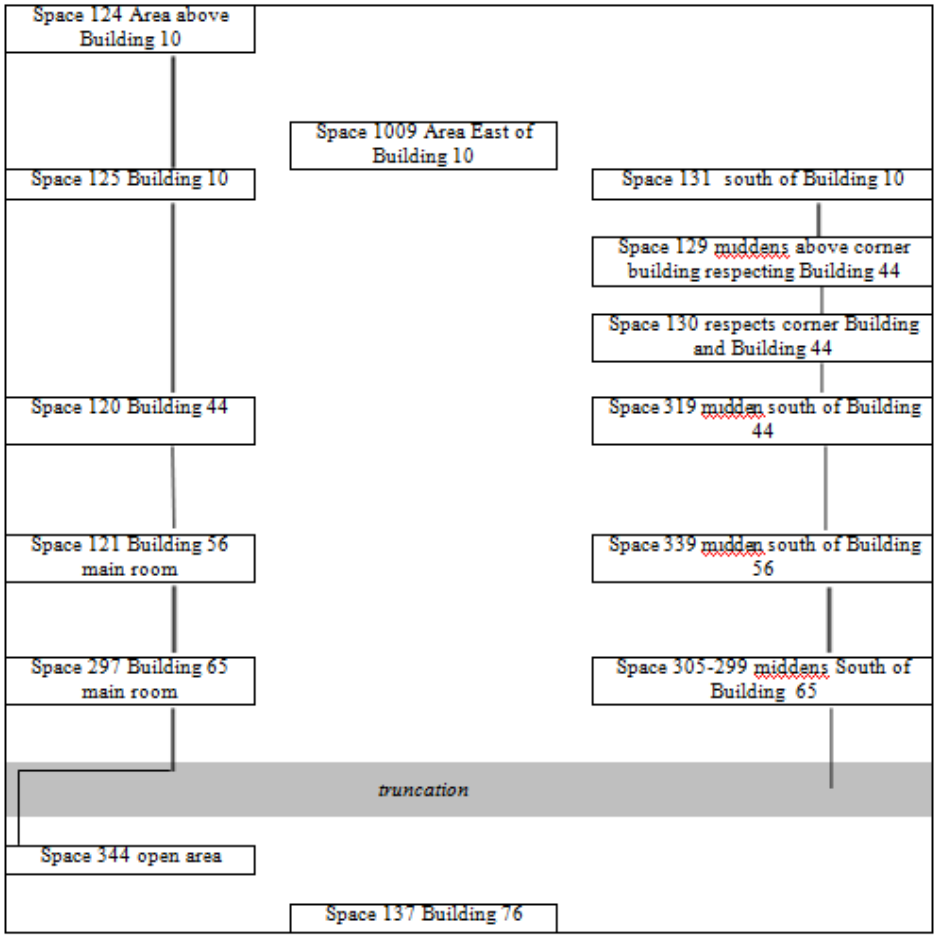


Figure 9.5
Section of Çatalhöyük South Area matrix showing midden association with long-lived building sequence B65 to 10

In order to compare the evidence to patterns in other aspects of the Çatalhöyük material culture, the specimens were grouped (*Table 9.9 & Appendix 12*). Six chronological analytical groups were constructed, ranging in size from 10 to 14. Although this group size is in keeping with previous practice (*Table 9.5*) the group size of the more secure samples often falls below 10, and it is preferable that any interpretation should be considered indicative rather than robust.

The datasets may also be considered spatially, investigating ways in which herding practice at Çatalhöyük might have been organised. It was possible to construct spatial groups with a large sample size, but the groups do not fully satisfy criteria needed to investigate differences between households, nor between neighbourhoods or areas, and interpretation

needs to proceed with caution. In general, midden material is likely to derive from houses other than those named, and might more accurately be related to the neighbourhood of the named houses. In addition, there are ample specimens from the neighbourhood of one household sequence (*Figure 9.5*), but it can only be compared to evidence that has been combined from all other household neighbourhoods, and therefore likely to give mixed signals. Secondly, and similarly, sample size reduces comparison between one area and a combination of evidence from all other areas. Lastly, the spatial specimens span the chronology of the settlement; a factor which might produce its own biases.

9.4. Sample preparation

Having collected all archaeological and modern specimens, a series of standard preparation protocols and laboratory procedures, following those used by Balasse (2002, 920) and Mainland (all references), were carried out in order to extract the data needed for analysis and interpretation. Details of these can be found in *Appendix 13*.

CHAPTER 10. OXYGEN ISOTOPE RESULTS AND ANALYSIS

10.1. Assessment of data

10.1.1. Sample size

Data were successfully obtained for 58 archaeological and 8 modern tooth specimens. The main reason for failure to obtain data was tooth friability leading to collapse during drilling. The sample size allowed the archaeological specimens to be studied chronologically in six analytical groups (*Table 9.9*) with a size-range is similar to that used in previous archaeological applications (*Table 9.5*). However, it is advisable to limit interpretations as indicative of any trends.

Between six to eight sequential samples were analysed in each modern and most archaeological teeth. As the second mandibular molar is known to form from birth until 12 months old, the $\delta^{18}O$ values in the enamel potentially derive from a complete annual cycle of ingested water. Sampling up the tooth column captures nearly the complete cycle, apart from the earliest phase around birth, which had been lost to tooth wear in all specimens. Where maximum and minimum $\delta^{18}O$ values are evident in the resulting near-annual curve, the mean and range can also be established. Limitations that might arise from particularly worn teeth, or from less than six specimens are borne in mind.

10.1.2. Evaluation of enamel carbonate diagenesis

Tooth enamel in archaeological specimens is potentially susceptible to diagenesis, particularly in the carbonate component (Iacumin *et al.* 1996; Wang & Cerling 1994). However, the isotopic composition of the carbonate component can easily be measured,

requiring less complex sample preparation in comparison with samples from the phosphate component. In order to assess any diagenetic influence, samples from two teeth were analyzed for both $\delta^{18}O_{PHOSPHATE}$ and $\delta^{18}O_{CARBONATE}$, and their correlation tested by linear regression analysis (*Appendix 14*). The solution for the linear regression of Tooth 50 (*Figure 10.1*) yielded:

$$\delta^{18}O_{PHOSPHATE} = (1.056\delta^{18}O_{CARBONATE}) - 11.02$$

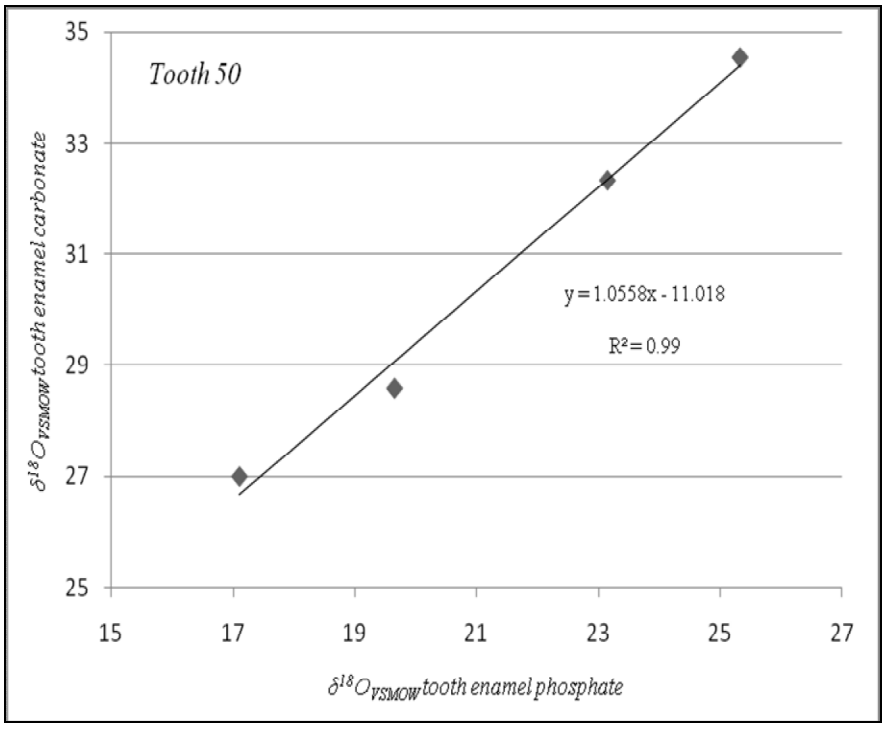


Figure 10.1
Chart showing the linear regression between $\delta^{18}O$ values in the phosphate and carbonate components of enamel in an archaeological sheep's tooth.

There is a very high correlation coefficient, $R^2 = 0.99$, which suggests negligible carbonate diagenesis. This linear regression is also in very good agreement with that of Iacumin *et al*. (1996, 4): $\delta^{18}O_{PHOSPHATE} = (0.98\delta^{18}O_{CARBONATE}) - 8.5$

The carbonate fraction of all other tooth enamel samples was therefore analysed for its oxygen isotopic composition. Analysis yields $\delta^{18}O$ values on the VPDB scale, which were

converted into $\delta^{18}O_{VSMOW}$ values using the following correlation (Friedman & O'Neil 1977):

$$\delta^{18}O_{VSMOW} = (1.0309\delta^{18}O_{VPDB}) + 30.9$$

10.1.3. Reproducibility of results

The estimation of variation is measured by the standard deviation shown in international and laboratory standards run with the tooth enamel samples. Typical analytical precision ranges from 0.01 to 0.45 per mil (*Appendix 13*) and falls well within the 7.24‰ range in oxygen isotope values given for Ankara (IAEA/WMO 2006). Therefore it is possible to proceed with confidence in data interpretation.

Specimen	*Mean $\delta^{18}O$ VSMOW*	*Range*	*Minimum*	*Maximum*	*Specimen*	*Mean $\delta^{18}O$ VSMOW*	*Range*	*Minimum*	*Maximum*
66	26.4	5.9	23.8	29.7	36	27.8	6.2	23.9	30.1
65	25.7	6.2	22.7	28.9	41	28.0	5.6	25.3	30.9
50	30.7	9.0	26.0	35.0	40	26.2	9.7	21.2	31.0
47	30.1	9.1	25.1	34.2	69	27.1	3.1	25.6	28.8
64	27.1	5.1	24.3	29.4	20	28.4	6.3	24.6	31.0
10	25.9	6.1	23.7	29.8	18	28.4	8.6	22.6	31.1
53	29.1	6.9	25.7	32.6	24	28.5	8.4	24.0	32.4
52	29.8	9.6	26.0	35.5	23	25.6	3.5	23.9	27.3
51	30.9	8.0	26.1	34.1	22	32.7	3.8	30.7	34.5
8	26.3	5.4	23.6	28.9	21	27.0	6.3	23.9	30.2
54	29.9	6.6	26.7	33.3	70	26.2	3.3	25.0	28.3
45	26.8	7.7	22.6	30.4	42	27.2	6.4	23.8	30.2
7	25.5	9.3	20.2	29.5	61	27.0	5.1	24.4	29.5
4	26.8	7.0	23.4	30.4	62	28.0	5.1	25.2	30.3
3	28.3	10.6	23.0	33.6	56	27.7	4.4	25.2	29.6
2	27.6	6.6	24.5	31.1	58	27.1	4.8	24.7	29.5
1	26.4	4.6	24.2	28.8	60	25.6	3.4	23.5	26.9
13	26.0	2.7	24.3	27.1	59	26.7	4.2	24.6	28.7
14	28.8	5.2	25.3	30.5	32	24.5	4.4	22.1	26.5
39	30.4	7.3	26.6	33.8	9	29.3	5.7	26.5	32.2
38	26.3	8.6	21.9	30.5	12	26.9	9.7	22.0	31.7
71	28.0	7.8	24.3	32.0	28	25.3	8.6	22.1	30.6
30	27.1	3.0	25.5	28.5	27	26.5	12.8	20.6	33.4
75	25.5	3.8	23.5	27.2	26	25.0	10.1	20.9	31.0
74	25.4	4.7	23.3	28.1	31	26.7	6.6	22.9	29.5
73	28.8	7.9	23.9	31.8	29	26.5	2.8	25.4	28.2
35	29.6	8.3	26.0	34.3	67	25.1	4.1	22.8	26.9
34	28.5	8.3	23.9	32.2	44	25.9	8.3	21.7	29.9
37	27.2	5.6	24.1	29.7	43	25.8	6.7	22.7	29.4
					All	**27.4**	**6.5**	**24.1**	**30.5**

Table 10.1
Summary of results of the oxygen isotope analysis ($\delta^{18}O_{VSMOW}$ ‰) of archaeological sheep teeth

The results of the oxygen isotope analysis of all tooth carbonate samples are presented in *Appendices 15* and *16*, and summarised in *Tables 10.1* and *10.2*. To more easily compare the GNIP $\delta^{18}O_{VSMOW}$ values in meteoric water to those in sheep enamel carbonate, a calibration has been used where appropriate (D'Angela & Longinelli 1990; Iacumin *et al.* 1996). The many limitations in the use of sheep tooth data as a direct climate proxy have been discussed in *Chapter 7*; however, climate evaluation is not the intention here. As all tooth specimens are taken from the same species from the same settlement, where all experience broadly similar climatic conditions, the convenience of calibration is valid.

On preliminary assessment, the pattern of cyclical variation recorded in the enamel of each tooth is consistent with annual seasonal cycles, and the range in $\delta^{18}O$ values is consistent with considerable summer enrichment due to net terrestrial evaporative conditions (P. Blisniuk *pers. comm.,* March 10th, 2008). The sampling strategy is of sufficient resolution to detect seasonal variation in the oxygen isotope composition of tooth carbonate.

Sample location	$\delta^{18}O_{VSMOW}$	*Mean*	*Range*	*Maximum*	*Minimum*
Küçükköy	Tooth enamel carbonate	27.4	6.9	30.9	24.1
Kızılkaya	Tooth enamel carbonate	26.2	4.0	28.3	24.3
Ayanis	Tooth enamel carbonate	26.6	7.7	30.9	23.2
Ankara	Tooth enamel carbonate (calibrated)	24.8	10.9	29.9	18.9
	Precipitation (GNIP)	-7.7	7.2	-4.4	-11.6
Dalbahce	Tooth enamel carbonate (calibrated)	22.0	27.4	34.8	7.4
	Precipitation (GNIP)	-9.5	18.2	-1.1	-19.2

Table 10.2
Summary of GNIP data and results of oxygen isotope analysis of modern sheep teeth.
$\delta^{18}O_{VSMOW}$ values in GNIP data have been converted to $\delta^{18}O_{CARBONATE}$ values using:
$\delta^{18}O_{PHOSPHATE} = (1.48\delta^{18}O_{INGESTED\ WATER}) + 27.21$ (*D'Angela & Longinelli 1990*)
$\delta^{18}O_{PHOSPHATE} = (0.98\delta^{18}O_{CARBONATE}) - 8.5$ (*Iacumin* et al. *1996*)

The results are analysed in three sections. The first explores the mean, range, maximum and minimum $\delta^{18}O$ values in the samples from each tooth, as indicators of the region in which each sheep spent its first year, and of the summer and winter extremes it experienced. The second section explores the earliest section of the curve of $\delta^{18}O$ values generated from sequential enamel sampling of each tooth column, in order to determine the birth season of each sheep. In the third section, movement of sheep to different locations during their first year is approached by combining information from the shape of the annual curve with the evidence of summer conditions discussed in the first section.

10.2. Regional and seasonal first-year rearing conditions

10.2.1. Establishing a model from the modern data

10.2.1.1. Global natural isotopes in precipitation (GNIP) data

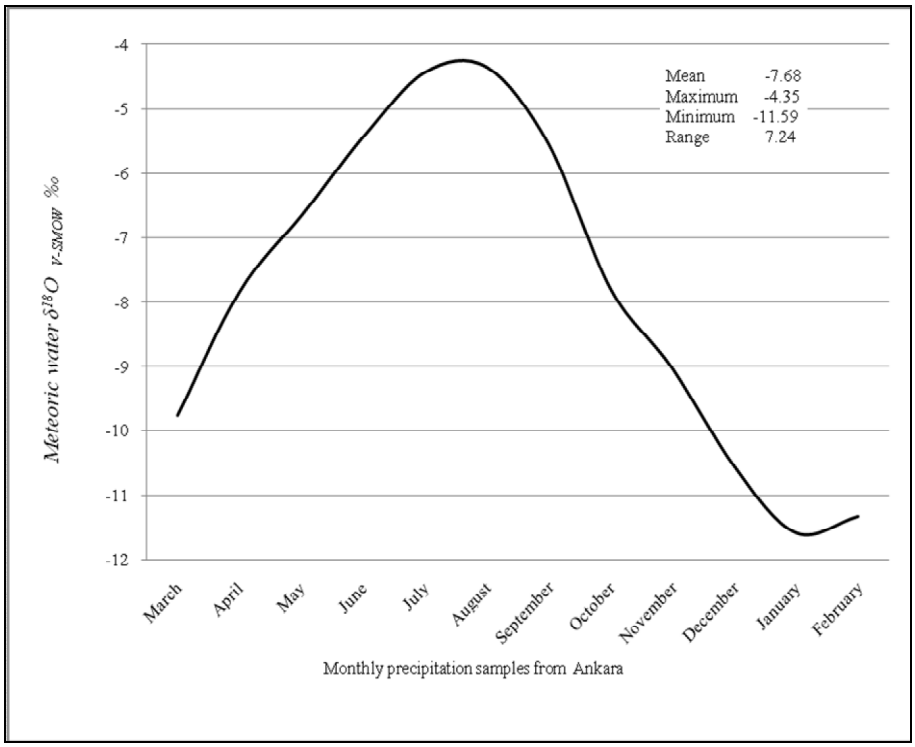


Figure 10.2
Chart of Ankara monthly $\delta^{18}O_{VSMOW}$ GNIP data, based on monthly weighted means over 40 years

The published database (IAEA/WMO 2006) of global natural isotopes in precipitation (GNIP) for Ankara is used as the underlying model in this research (*Figure 10.2*). The GNIP data provides the weighted annual and monthly mean, range, maximum and minimum $\delta^{18}O$ values. Inter-annual variability is modelled from 13 years of complete records (*Table 10.3*). The variability is added to the estimated analytical error to provide the margin of error used in interpretation. It is to be noted that the inter-annual variability is very low.

Ankara (GNIP) meteoric water oxygen isotope values, calibrated to $\delta^{18}O_{CARBONATE}$	*Mean over 13 years*	*Variation from the 13 year mean*	
		Plus	*Minus*
Mean	24.8	0.4	0.6
Range	11.8	2.0	2.3
Minimum	19.0	1.4	1.6
Maximum	29.6	1.7	1.5

Table 10.3
Inter-annual variability modelled from Ankara GNIP data

10.2.1.2. Modern tooth data

Modern tooth data provide information on water ingested by sheep in three environmental settings relevant to this research, as outlined in *Chapter 9*. Two of these locations, Küçükköy and Kızılkaya are compared to published data on meteoric water in Ankara, and the third, Ayanis, is compared to Dalbahce published data. The geographical relationship between Küçükköy, Kızılkaya and Ankara is similar to that between Ayanis and Dalbahce. The published data from Dalbahce are so variable that they cannot usefully be displayed graphically alongside data from Ankara and the modern tooth specimens; consequently they are inserted into the graphs as text (*Figures 10.3, 10.4 & 10.5*). The sample size for each location is small, and might contribute error; this should be borne in mind.

The inter-annual variability that may be expected in the tooth data is modelled using that established in the published data. The mean (*Figure 10.3*), range (*Figure 10.4*), maximum and minimum (*Figure 10.5*) $\delta^{18}O$ values in each modern tooth are compared to those in the annual GNIP data. As the life-history of each modern sheep is known, their tooth data can be compared to the GNIP data for interpretation. The interpretation of the tooth data then provides the model for assessing the archaeological data.

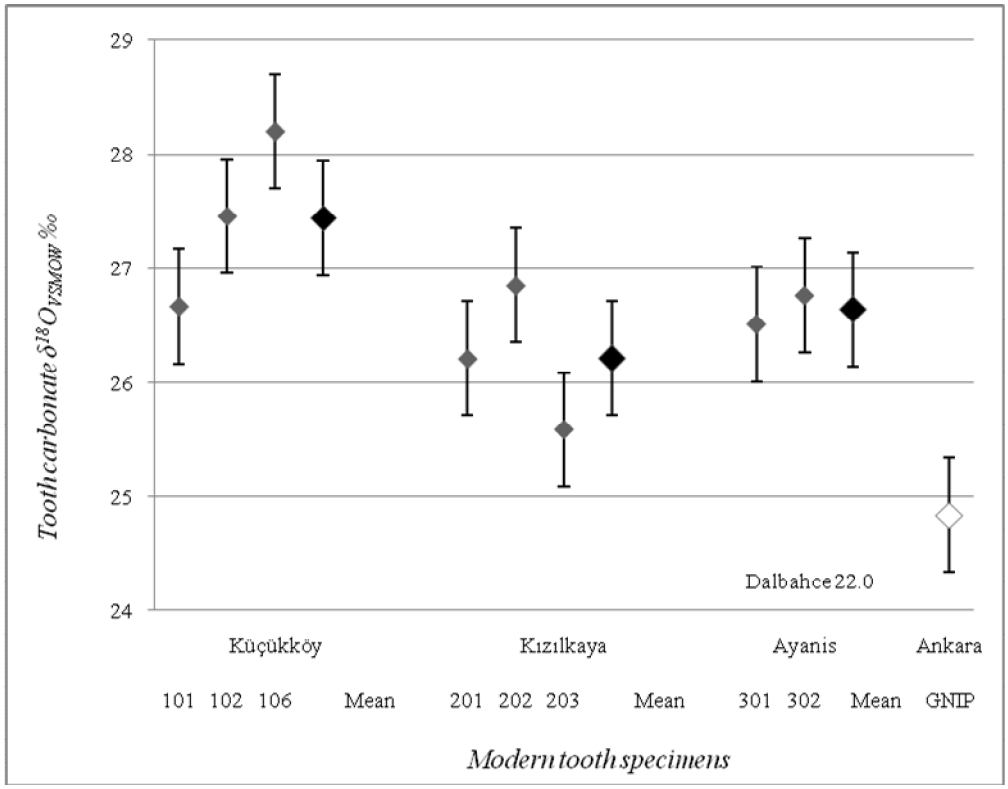


Figure 10.3
Mean $\delta^{18}O$ values in modern sheep tooth specimens

Each sheep specimen is numbered, and for each group from the same village, a mean is displayed using a larger marker. On the far right, the GNIP information is displayed graphically for Ankara, with a white marker, and textually for Dalbahce

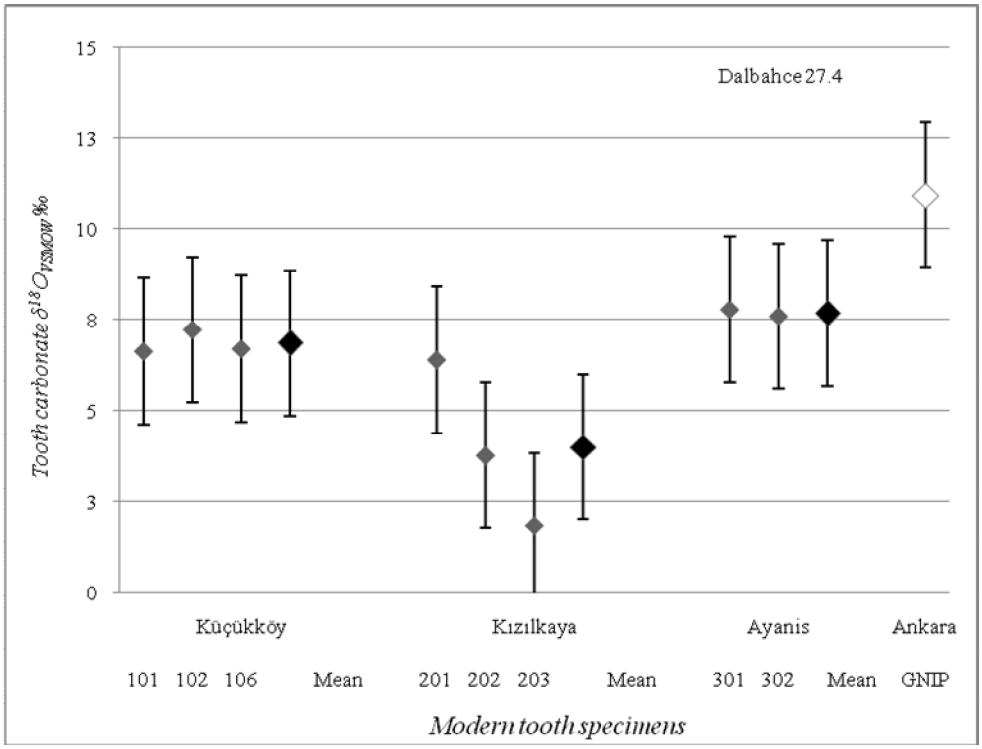


Figure 10.4
Range in $\delta^{18}O$ values in modern sheep tooth specimens
(see Fig. 10.3 for explanatory notes)

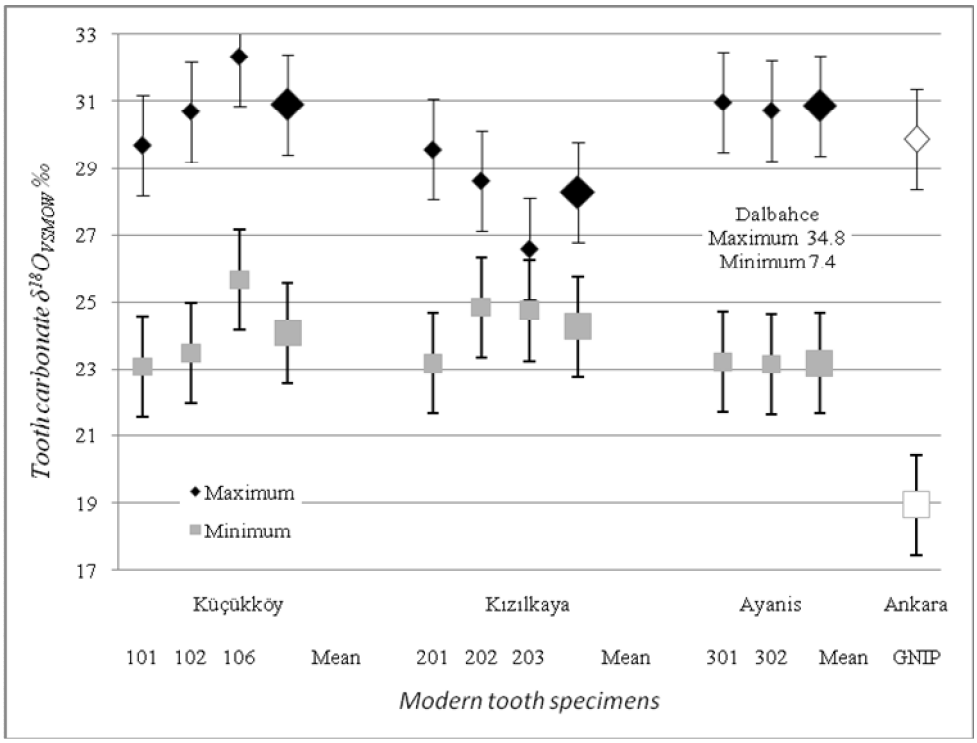


Figure 10.5
Maximum and minimum $\delta^{18}O$ values in modern sheep tooth specimens
(*see* Fig. 10.3 *for explanatory notes*)

The tight clustering of $\delta^{18}O$ values in the two Ayanis sheep reflects their birth in the same year, therefore experiencing the same conditions. Küçükköy and Kızılkaya specimens come from sheep born in different years, where variability in weather conditions might be expected. In all measures, samples fall within the expected variability, but in many measures, there is distinct inter-location variability. These inter-location differences and intra-location clusterings offer reassurance about the small sample sizes.

Mean $\delta^{18}O$ values of sheep tooth samples can only summarise the ingested water conditions over one year (*Figure 10.3*). Conditions might vary with inter-annual climate variation, with different herding strategies, or with movement across varying topographies. Compared to the Ankara GNIP data, all mean $\delta^{18}O$ values in the modern sheep teeth are enriched, by 2.6‰ at Küçükköy and 1.4‰ at Kızılkaya; $\delta^{18}O$ values in Ayanis sheep teeth are enriched by 4.6‰ compared with Dalbahce. Kızılkaya and Ayanis have quite similar mean $\delta^{18}O$ values whilst the Küçükköy mean is higher.

As seasonal signatures are dampened by the $\delta^{18}O$ values of enamel formed earlier or later in the year, it might be expected that maximum and minimum $\delta^{18}O$ values would be less extreme than in meteoric water. Nevertheless the effect would be the same in all sheep tooth specimens, and so any differences between them must have other causes. However, tapped water from long residency in reservoirs or aquifers is mixed, and would therefore have an averaged annual oxygen isotope signature (Darling *et al.* 2006). As Küçükköy sheep are known to have drunk such water in summer (*Table 9.1*) their summer $\delta^{18}O$ values would be dampened. This would not be the case for Kızılkaya and Ayanis sheep, as they relied on seasonal water. With these caveats in mind, the range between maximum and minimum $\delta^{18}O$ values gives some indication of the extremes experienced by sheep in their drinking water.

The annual range of $\delta^{18}O$ values in modern sheep tooth specimens (*Figure 10.4*) is narrower than the meteoric water range – for Küçükköy 4.1‰ less, Kizilkaya 6.9‰ less, and Ayanis

19.7‰ less. For the range, Ayanis sheep are more similar to Küçükköy sheep, but once again Kızılkaya sheep have lower values that those from Küçükköy. The Küçükköy range might be dampened solely due to the effects of enamel formation and summer tap water; the uniformity between individual sheep supports this proposal. However, although Kızılkaya and Ayanis summer drinking water should be more enriched than Küçükköy tap water, they have dampened $\delta^{18}O$ values relative to Küçükköy. This suggests there are other influencing factors. The significant narrowing of the range in $\delta^{18}O$ values in Ayanis sheep suggests that they, in particular, were protected from seasonal extremes in their first year.

Minimum $\delta^{18}O$ values are associated with winter, when temperatures are colder and precipitation higher. At this time of year sheep receive all their water from plant surfaces and leaf-water. Enamel formation would dampen the seasonal signature; therefore inter-tooth variation can be associated with annual differences in weather conditions, or protection from the cold. Minimum $\delta^{18}O$ values in all tooth specimens (*Figure 10.5*) are higher than GNIP minimum values, but to varying degrees – Küçükköy 5.13‰, Kizilkay 5.32‰, and Ayanis 15.78‰. The net result is that all specimens cluster within 1.1‰ of each other, showing remarkable uniformity. Winter protection is known to be offered to herds in all three areas when the ground is frozen or the snow more than 10cm deep.

Differences in maximum $\delta^{18}O$ values could be a function of the inter-locality annual variation in summer weather, or of differences in the evaporative status of the water to which the sheep had access. Again, some dampening effect due to enamel growth patterns would be expected. There is more variability in maximum $\delta^{18}O$ values between areas than for the minimums, suggesting that sheep have more tolerance to heat than to cold, or that herders are less able to control summer conditions. Küçükköy and Kızılkaya samples all fall within inter-annual variability of maximum temperatures (*Figure 10.5*), modelled by the GNIP data. Küçükköy sheep, which ingest water in stressed, exposed conditions, have $\delta^{18}O$ values 1.1‰ higher than the Ankara GNIP maximum, while Kızılkaya sheep, drinking

shaded perennial stream water, have $\delta^{18}O$ values that are 1.6‰ lower. In summer, Ayanis sheep ingest water with significantly lower $\delta^{18}O$ values (by 3.95‰) than the Dalbahce GNIP maximum. It is known that Ayanis herds are taken onto the hillsides in summer to avoid extreme summer heat.

10.2.1.3. Summary

Variation in the data between sheep raised in three environmental settings in Anatolia may be interpreted using the known histories of the sheep and the published GNIP data. Values within each area tend to cluster, and fall within inter-annual variability parameters. In some measures there is little difference between areas, in others, differences are apparent. Minimum values are remarkably similar in all areas, suggesting highly controlled winter drinking for the sheep.

Kızılkaya sheep experience the narrowest range in the conditions of their upbringing during their first year, primarily due to sourcing their summer drinking water from a cool, non-evaporative, perennial stream. Yet, ingested water at Kızılkaya does not deviate from meteoric water as greatly as ingested water at Ayanis; within the natural protection of the river valley, management might be relatively easier. The mean values in Kızılkaya specimens have the greatest intra-herd variety, which suggests that management could be more flexible and less controlled.

Ayanis sheep, on the other hand, have been raised in winter and summer conditions that differ considerably from the annual environmental conditions of the settlement, suggesting quite significant herd-management intervention. The more extreme summers necessitate the movement of herds to cooler regions; summer movement onto the hillsides is reflected in highly depleted maximum $\delta^{18}O$ values in the sheep tooth carbonate. Küçükköy sheep have higher mean $\delta^{18}O$ values than those from Kızılkaya, a reflection of stressed summer

conditions on the plains, where no herding strategies exist to move animals to cooler conditions.

In summary, both modern datasets may be used to model the archaeological data (*Table 10.4*).

- $\delta^{18}O$ values in sheep enamel carbonate do not stand as proxies for exact climate reconstruction, but clearly follow ingested water $\delta^{18}O$ values.
- As all specimens are from the same species, variation in $\delta^{18}O$ values in tooth carbonate samples can be ascribed to variation in $\delta^{18}O$ values in ingested water.
- Mean $\delta^{18}O$ values give a general indication of variation within any assemblage, and also of any marked deviation from a regional norm.
- The range in $\delta^{18}O$ reflects the degree of seasonality experienced by the sheep and, in comparison to the range in meteoric water values, indicates how protected they are from seasonal weather extremes.
- Minimum $\delta^{18}O$ values give information on winter temperatures and precipitation rates. Marked deviation from meteoric water values probably indicates human intervention. In modern sheep, minimum $\delta^{18}O$ values of 23–25‰ are typical for ingested water in winter, and indicate shelter from extreme cold.
- Maximum $\delta^{18}O$ values give information on summer temperatures and the extent to which ingested water is evaporative. Low readings suggest some amelioration from stressed evaporative conditions. More extreme deviation from the meteoric water $\delta^{18}O$ maximum, particularly if a number of specimens share very similar maximum values, indicates a high degree of management. Less extreme lowering of maximum $\delta^{18}O$ values, and less uniformity within a group, suggests more local solutions to avoiding summer heat stress.
- Outliers might represent animals brought into the settlement later, having spent the earlier part of their lives elsewhere.

Table 10.4
Summary of the use of oxygen isotope data in modern sheep teeth

10.2.2. Archaeological interpretation

10.2.2.1. Overview and analysis of archaeological data

The archaeological data are tabled in *Appendix15*, summarised in *Table 10.1*, and graphically displayed in *Figures 10.6, 10.7* and *10.8;* all $\delta^{18}O$ values are expressed as

$\delta^{18}O_{CARBONATE}$. The inter-annual variability in all measures (*Table 10.3*) is calculated for the archaeological data (*Table 10.5*); it is shown on all charts as a grey-coloured confidence band. As discussed in *Chapter 9*, there is some variation in the contextual resolution of the specimens; in the charts the display markers for specimens with good contextual security are filled in solid. The tooth specimens are presented in approximate chronological order spanning the range of the Neolithic occupation (*Appendix11*).

Mean $\delta^{18}O_{CARBONATE}$ values of all archaeological specimens		*Confidence limits, established from Ankara GNIP data*	
		Plus	*Minus*
Mean	27.4	27.8	26.8
Range	6.5	8.5	4.2
Minimum	24.1	25.5	22.5
Maximum	30.5	32.2	29.3

Table 10.5
Inter-annual $\delta^{18}O_{CARBONATE}$ variability in Çatalhöyük specimens, calculated from Table 10.3

Of the less contextually secure specimens, four clustering to the right of the charts have very high ranges and fairly high maximums and low minimums; they are discussed further in *Chapter 12*, as are all such outliers. Of the short teeth that were only sub-sampled five times, Tooth 22, has high mean, maximum and minimum $\delta^{18}O$ values, but should be viewed with caution as toothwear might have removed the enamel with minimum $\delta^{18}O$ values.

Even after excluding less contextually secure teeth, it is apparent that in all measures, throughout the occupation, there are $\delta^{18}O$ values that exceed predicted variability. As in the modern baseline, there is more variability in maximum than minimum values (*Figure 10.8*). Very few minimum $\delta^{18}O$ values fall below 23‰, similar to over-wintering conditions experienced by modern sheep.

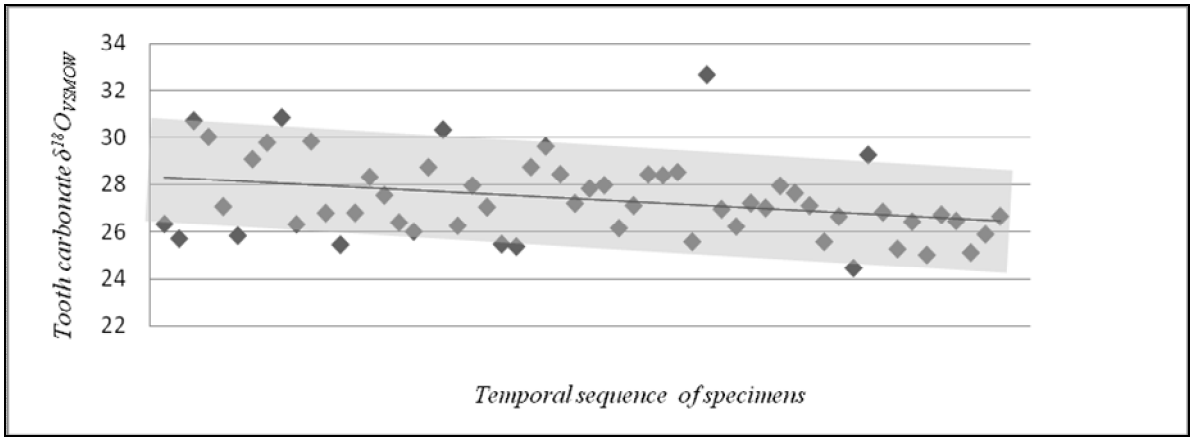


Figure 10.6
Chart showing temporal sequence of mean $\delta^{18}O_{CARBONATE}$ values in Çatalhöyük teeth, from the earliest occupation levels (on the left) until the end of the Neolithic occupation (on the right), modelled inter-annual variability displayed as grey confidence band

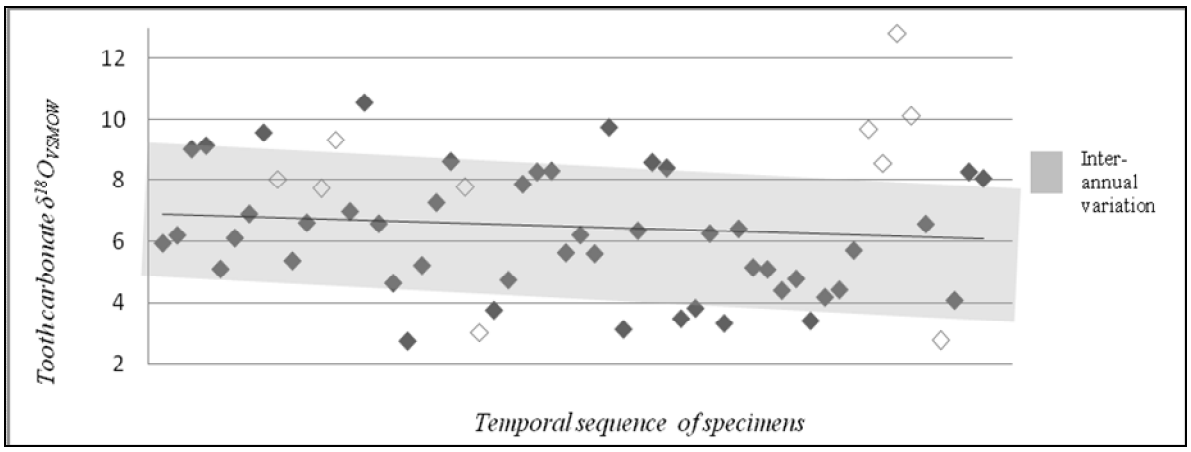


Figure 10.7
Chart showing temporal sequence of the range in $\delta^{18}O_{CARBONATE}$ values in Çatalhöyük teeth

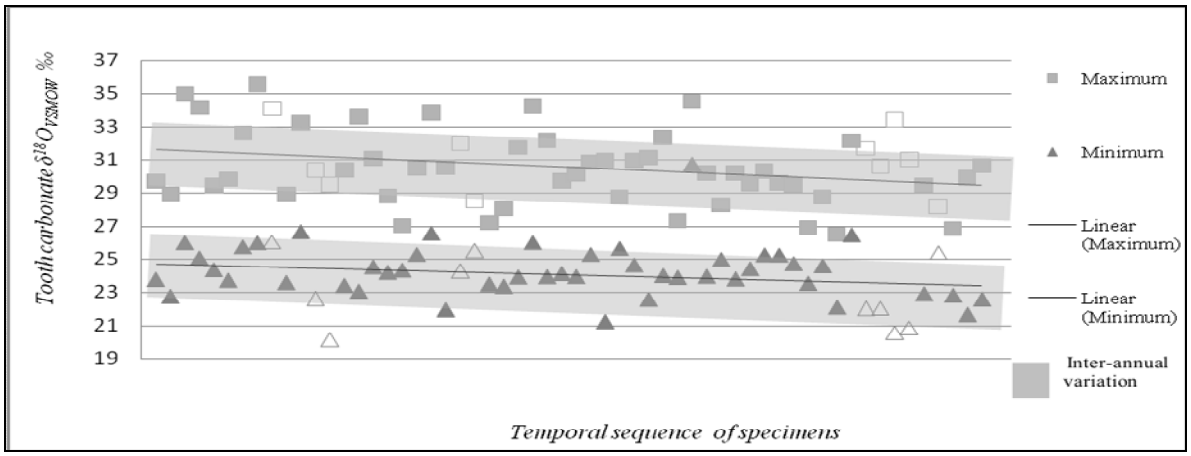


Figure 10.8
Chart showing temporal sequence of maximum and mimimum $\delta^{18}O_{CARBONATE}$ values in Çatalhöyük teeth

The linear trend lines in all charts show a slight, but steady fall in $\delta^{18}O$ values over time in minimum and maximum values (*Figure 10.8*). At the same time, the variation in maximum $\delta^{18}O$ values decreases (excluding the outliers). Over time, more sheep were having access to progressively less isotopically enriched water in summer and winter. The decline in winter and summer $\delta^{18}O$ values might be due to a steady fall in temperatures or higher precipitation over the 1200 years of Neolithic occupation; however this is not consistent with palaeoenvironmental interpretation *(Chapters 5 &7*). In addition, climate change does not provide a ready explanation for the decline in inter-annual summer variability. Alternatively, the sheep were being given progressively more protection from summer extremes, as experienced by modern sheep from Kızılkaya and Ayanis, and in contrast to sheep from Küçükköy.

10.2.2.2. Chronological analysis of archaeological data

In the previous section, the archaeological specimens were presented in a chronological sequence, and whilst their oxygen isotope data showed a trend towards more uniformity and less enriched summer water, they did not readily fall into clusters which might indicate more abrupt temporal changes. These trends, and any others that emerge, may be tested by examining the evidence in the six chronologically-sequenced analytical groups (*Table 9.9*), although the small sample size of these groups should be born in mind. The results for all specimens are summarised in *Table 10.6*, and the results for the specimens with greater contextual resolution are displayed as box-plots in *Figure 10.9, 10.10* and *10.11*. Outliers will be identified and discussed in *Chapter 12*.

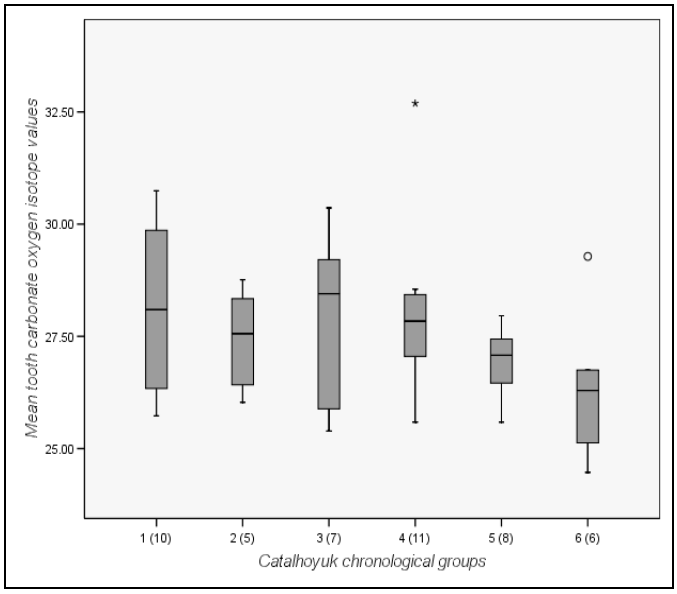


Figure 10.9
Box-plots comparing the median $\delta^{18}O_{CARBONATE}$ values between Çatalhöyük chronological analytical groups

(*The black bar across each box gives the median value, the grey box represents the interquartile range, the extended vertical lines add the first and fourth quartiles, and circles and stars represent outliers*.)

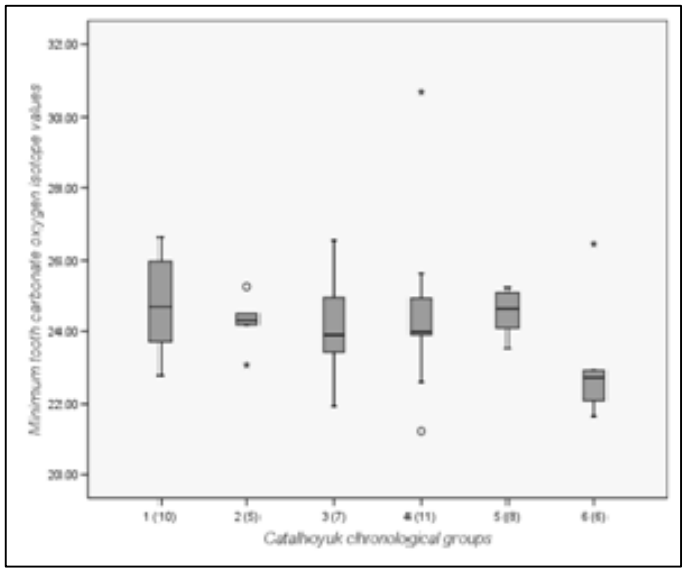


Figure 10.10
Box-plots comparing the minimum $\delta^{18}O_{CARBONATE}$ values between Çatalhöyük chronological analytical groups

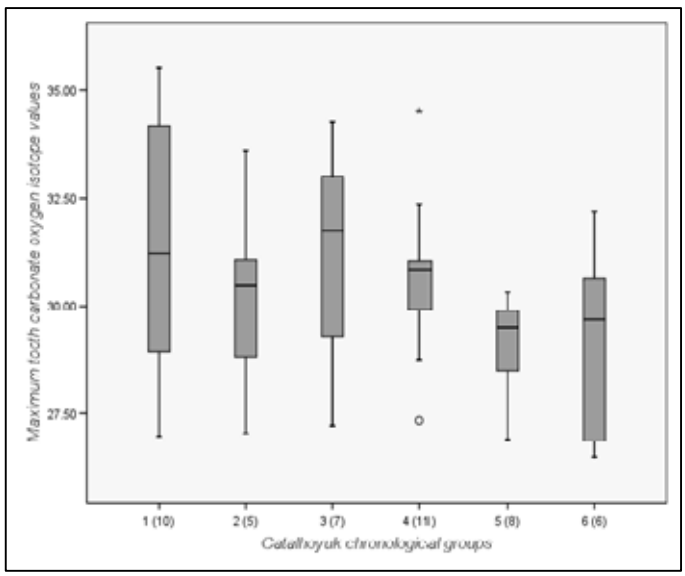


Figure 10.11
Box-plots comparing the maximum $\delta^{18}O_{CARBONATE}$ values between Çatalhöyük chronological analytical groups

Chronological groups (N° samples)	*Median*	*Range*	*Minimum*	*Maximum*
Group 6 (11)	26.5	6.5	23.3	29.8
Group 5 (8)	26.9	4.6	24.5	29.1
Group 4 (11)	27.9	6.1	24.5	30.6
Group 3 (9)	27.9	7.1	24.3	31.4
Group 2 (8)	28.4	7.1	24.9	32.0
Group 1 (11)	28.4	7.1	24.9	32.0

Table 10.6
Summary $\delta^{18}O_{CARBONATE}$ values in Çatalhöyük chronological analytical groups

The earliest four analytical groups (1–4) have higher median values, and the last two (5–6) have decreasingly lower values (*Figure 10.9*). The evidence suggests that the decline in median $\delta^{18}O$ values over time largely took place from group 5 onwards. The earlier three groups also have a wider spread in median $\delta^{18}O$ values, showing more variety between ingested water conditions experienced by the sampled sheep in each group. The outlier in group 4 may be disregarded as it is the short Tooth 22; however Tooth 9, the outlier in group 6, is discussed in *Chapter 12*.

The minimum $\delta^{18}O$ values in each group cluster tightly, with little variety or change, within the 22.46‰ to 25.46‰ confidence band (*Figure 10.10*). Despite differences in the Neolithic climate these values closely replicate those for modern sheep. The exception is group 6; here the minimum $\delta^{18}O$ values are considerably lower. Two outliers that have more than 6 samples per tooth (Tooth 40 in group 4, Tooth 9 in group 6) are discussed in *Chapter 12*.

The trends in the maximum $\delta^{18}O$ values in each chronological group closely follow those in the median $\delta^{18}O$ values (*Figure 10.11*), and it is probable that changes in maximum values are the main source of median changes. Almost all data fall within modelled inter-annual

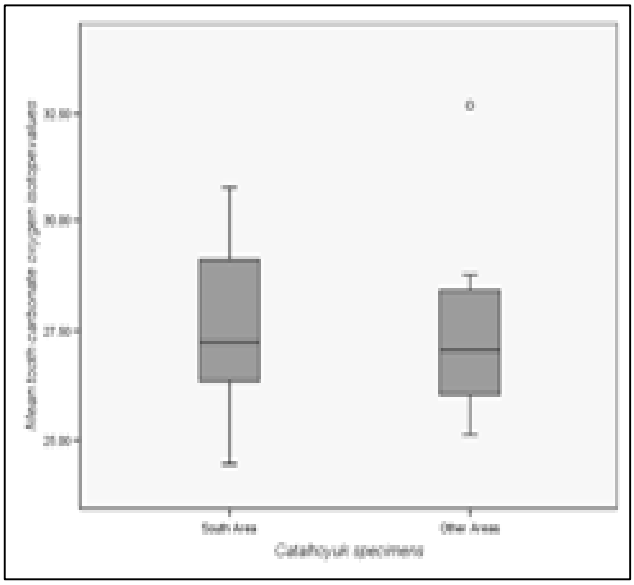
variability; nevertheless, there is a drop in values in the last two groups. It suggests that from group 5 onwards, sheep were ingesting water from less evaporative sources. This might result from a changing summer climate, if so; this starts earlier than a possible change in the winter climate. Alternatively, the data might result from watering and pasturing sheep in cooler, less evaporative conditions. Generally, there is greater intra-group variety in maximum $\delta^{18}O$ values, as was seen in modern datasets. Groups 4 and 5 are the most tightly clustered, but this is not a trend that is continued later into group 6 (even with the outliers excluded). All outliers displayed in the charts may be discounted as they are short tooth specimens with missing maximum values.

Chronological patterns in oxygen isotope data generally fall within modelled inter-annual variability. This is convincing evidence that the sheep experienced regionally typical conditions in their ingested water during their first year. There are only two outliers with signatures that might suggest otherwise.

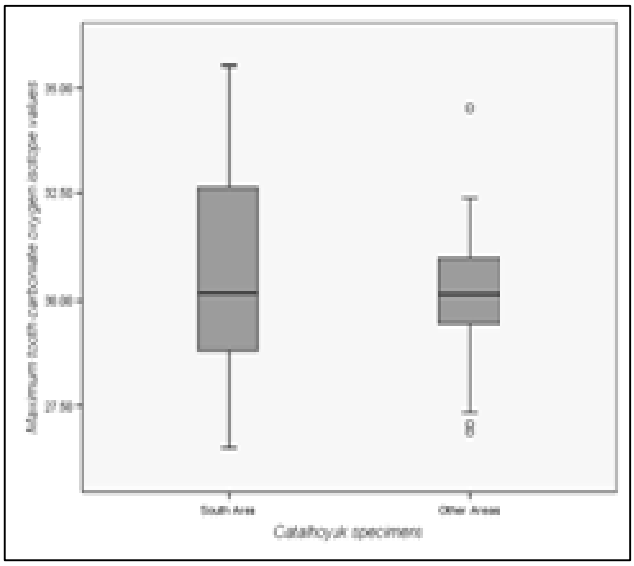
There are, nevertheless, some tentative observations on chronological changes that may be made. Firstly, the greatest uniformity appears to be in winter-ingested water, which only falls below the modelled common minimum in group 6. In summer evidence might indicate more uniformity in conditions experienced by sheep in groups 4 and 5, with more benign conditions in groups 5 and 6, than in the earlier three groups.

10.2.2.3. Spatial analysis of archaeological data by area of excavation

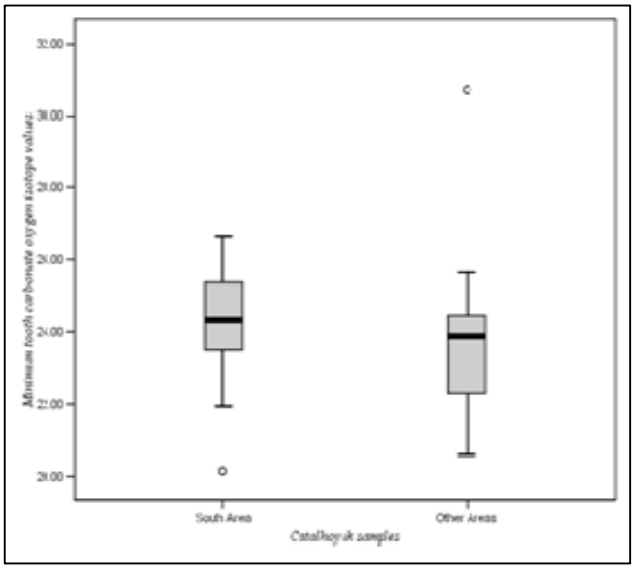
Results from the South Area of Çatalhöyük (38 specimens) are compared with those from other areas (20 specimens) in *Figure 10.12*. There are no significant differences, and thus no evidence that sheep, whose remains were in different parts of the settlement, were raised in different conditions during their first year of life.



A.



B.



C.

Figure 10.12
Box-plots comparing
(A) median
(B) minimum
(C)maximum

$\delta^{18}O_{CARBONATE}$ values between Çatalhöyük South Area (on the left) and other Areas (on the right)

10.2.2.4. Spatial analysis of archaeological data by association with building type

In the South Area, 20 specimens from middens associated with the neighbourhood of a long-lived sequence of buildings (B65–56–44–10) may be compared to 17 specimens from middens associated with short-lived-house neighbourhoods (*Figure 10.13*). The long sequence has added interest, in that Building 44 is an example of a 'history house', as a possible focus of neighbourhood activity.

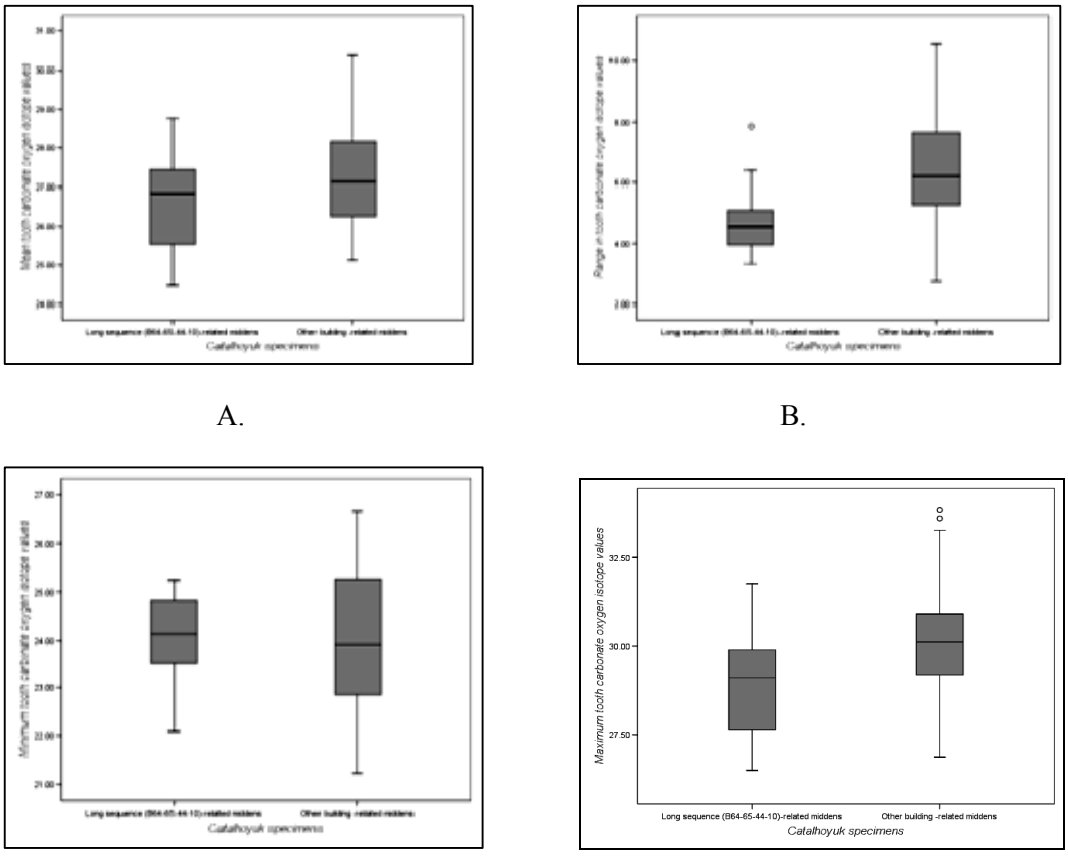


Figure 10.13
Box-plots comparing (A) median,(B) range,(C) minimum and(D) maximum $\delta^{18}O$ values between (64-56-44-10) long-sequence building (on the left) and short-lived buildings (on the right) in Çatalhöyük

The two datasets have nearly identical median values, confirming that very similar overall annual conditions were experienced by the sheep. However the range in $\delta^{18}O$ values in the dataset from the long-lived sequence neighbourhood is narrower and more uniform, as a result of higher minimum and lower maximum $\delta^{18}O$ values. These differences largely fall

within modelled inter-annual variability; nevertheless, both datasets are large and extend over long overlapping chronologies, and it is difficult to explain how one group could experience greater inter-annual climatic variability than the other. If it is correct that inter-annual variability cannot explain the observed differences, then the reduction in experienced seasonal extremes probably results from sheep having spent their first year in more controlled summer and winter conditions.

10.3. Birth season

10.3.1. Establishing a model from the modern data

The Ankara GNIP data (IAEA/WMO 2006) provides weighted monthly $\delta^{18}O$ values, which can be used to generate a series of annual curves, each starting at a different point in the year (*Appendix 17*). Enamel formation in sheep second-mandibular molars is known to take place from birth until approximately 12 months, proceeding evenly from the occlusal surface to the crown cervix (Suga 1982; Weinreb & Sharav 1964). Thus sequential samples from unworn teeth also give annual curves of $\delta^{18}O$ values that would start in their birth season (Fricke & O'Neil 1996).

The results from sequential sampling of modern teeth are given in *Appendix 16.* Sequential $\delta^{18}O$ values are plotted against sampling distance from the cervix, four of which are shown in *Figures 10.14* and *10.15*. The sample nearest to the cervix is plotted on the far right of the curve. The cervix is the fixed point on the curve, where the latest enamel was formed at *c.* 12 months. The plot on the far left represents the sample nearest the occlusal surface. However, as tooth-wear has removed some of the earliest enamel formed around birth, and as the rate of tooth-wear is probably not constant, the plot on the far left of the curve cannot be precisely positioned or aged, and sequential sampling does not produce a full annual curve of $\delta^{18}O$ values.

As enamel formation is completed 12 months after birth, or one annual cycle later, it is possible to extrapolate the birth season from the $\delta^{18}O$ value of the sample closest to the cervix. For example, Teeth 102 (*Figure 10.14*) and 302 (*Figure 10.15*) have annual cycles that are nearly complete, so the plots on the far left can be associated with the earliest enamel formation and therefore the birth of the sheep. The plots on the right are associated with the latest enamel formation one year later than the first sample, and closely match the $\delta^{18}O$ values associated with the time of birth.

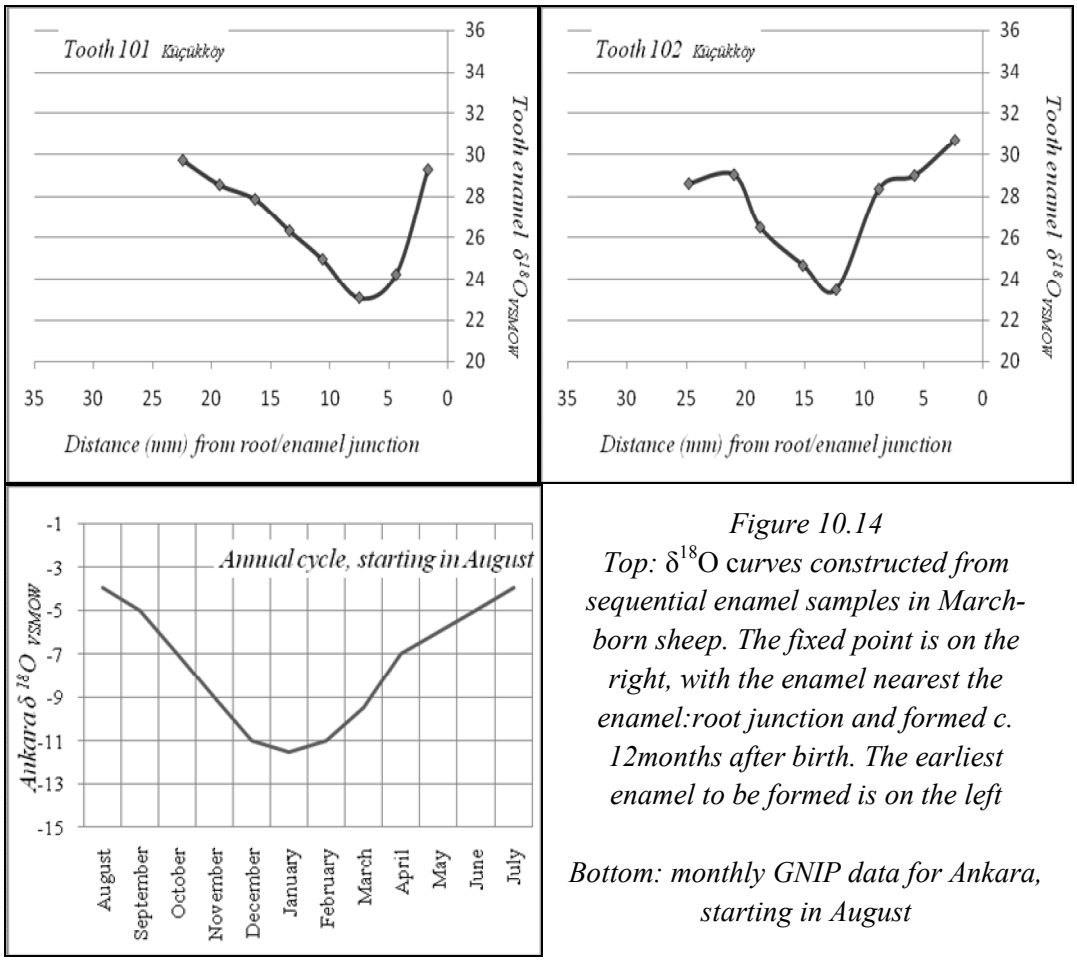


Figure 10.14
Top: $\delta^{18}O$ curves constructed from sequential enamel samples in March-born sheep. The fixed point is on the right, with the enamel nearest the enamel:root junction and formed c. 12months after birth. The earliest enamel to be formed is on the left

Bottom: monthly GNIP data for Ankara, starting in August

The curves of sequential $\delta^{18}O$ values in modern specimens can be compared to the shape of the annual curves generated from Ankara GNIP data. In *Figure 10.14*, Küçükköy lambs are born in early spring, in March, however their curves do not follow the March GNIP pattern (*Figure 10.2*). The Ankara GNIP curve for March ends, as expected, just as meteoric water $\delta^{18}O$ values rise after the depleted winter trough. Küçükköy curves more closely resemble

August meteoric water $\delta^{18}O$ curves, finishing as the most enriched summer $\delta^{18}O$ values are approached. This delay of five months in the Küçükköy $\delta^{18}O$ values is consistent with the known time-lag in oxygen uptake in the precipitating enamel of small-bodied domestic caprines (Balasse 2002).

Ayanis sheep are known to have been born in late spring, in May–June, but have $\delta^{18}O$ curves that more closely match GNIP meteoric water curves for October–November (*Figure 10.15)*. In Ayanis sheep, too, there is a five-month time-lag between enamel $\delta^{18}O$ values and meteoric water $\delta^{18}O$ values. In addition there is a clear difference in the final section of the March birth curves and the May–June birth curves. This difference is great enough to discriminate between births in the earlier and later parts of one season.

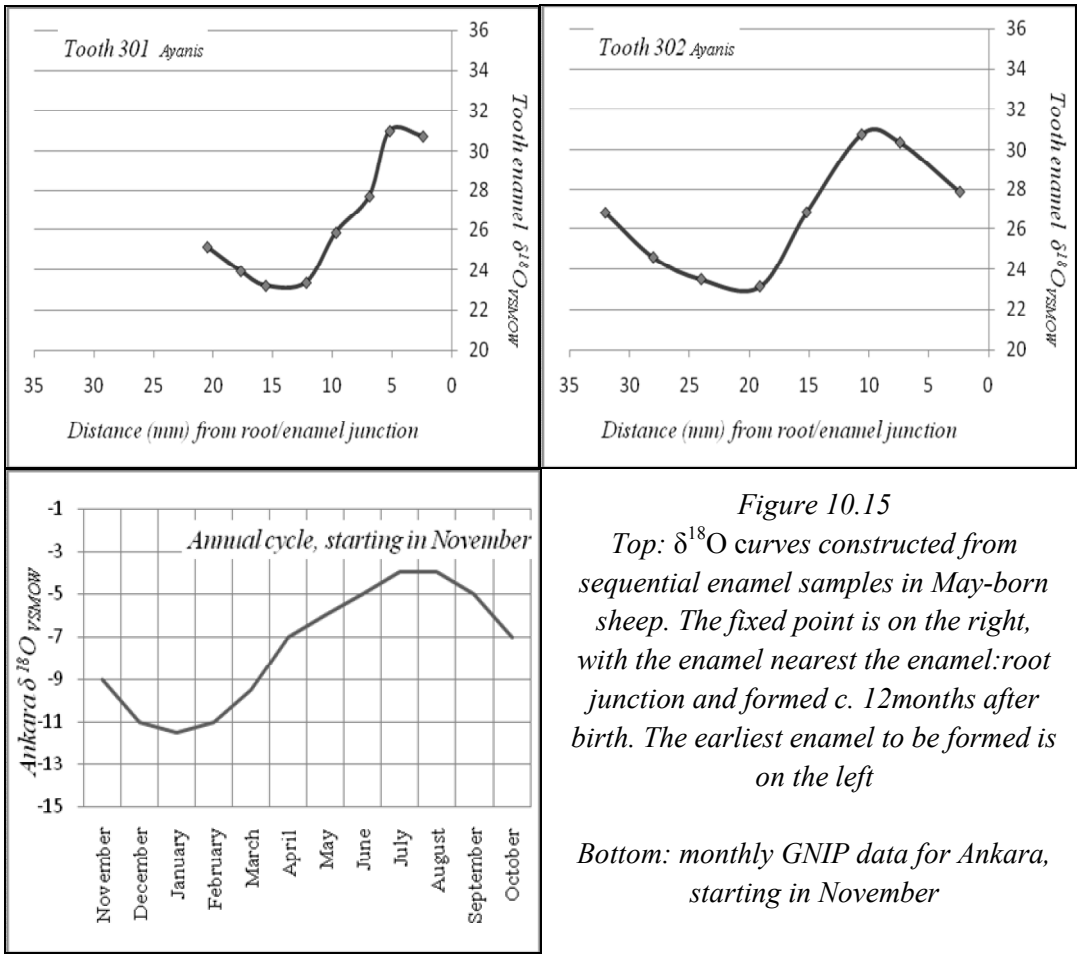


Figure 10.15
Top: $\delta^{18}O$ curves constructed from sequential enamel samples in May-born sheep. The fixed point is on the right, with the enamel nearest the enamel:root junction and formed c. 12months after birth. The earliest enamel to be formed is on the left

Bottom: monthly GNIP data for Ankara, starting in November

10.3.1.1. Summary

1. It is possible to extrapolate the birth season of archaeological sheep by examining the shape of the final section of the curve of sequential $\delta^{18}O$ values, nearest the cervix and on the right-hand side of the charts.
2. The shape of the final part of the curve can be compared to GNIP data curves constructed to start in different months, in order to identify which GNIP curve provides the best match.
3. Five months can be subtracted to account for the known time-lag in enamel formation, in order to reach a proposed birth season.

In this thesis, the birth months of the archaeological sheep will be interpreted using the model presented below in *Table 10.7*.

Month of birth	*5 month time-lag shown by GNIP*	*Last phase of curve*	*Broad model*
January	June	50% risen	Late winter birth
February	July	75% risen	
March	August	Fully risen	Spring birth
April	September	Entering cusp	
May	October	Cusp	Late spring birth
June	November	Falling from cusp	
July	December	50% fallen	Summer birth
August	January	Fully fallen	
September	February	Low trough appearing	Autumn birth
October	March	Trough	
November	April	Emerging from trough	
December	May	25% risen	Winter birth

Table 10.7
Model of birth season interpretation of sequential curves of $\delta^{18}O$ data in sheep tooth enamel

10.3.2. Archaeological interpretation

10.3.2.1. Overview and analysis of data in archaeological specimens

The pattern that is the most commonly repeated in the archaeological specimens (*Figure 10.16, Appendix 18 & Table 10.8*) most closely resembles the modern Ayanis specimen, Tooth 302 (*Figure 10.15*), which provides a clear example of an annual curve from a sheep born in May–June. If this is correct, twenty-six archaeological sheep were born in late spring to early summer. Only eight specimens resemble the curve modelled by the Küçükköy examples with March births and might be interpreted as coming from sheep born in early spring. Eleven specimens fall between and, by extrapolation from the modern examples and from GNIP data, can be interpreted as April-born lambs. Following the May–June group, there are five specimens which, by extrapolation from modern examples and GNIP data, might be from lambs born later in early to mid –summer.

Within the large May–June group, twelve specimens clearly include maximum and minimum parts of the curve, but fourteen teeth are worn at the occlusal end of the column such that the minimum values are uncertain. In all groups there are some that have curves with a smaller range. Of fifteen specimens in this category, eleven have long curves from tooth columns more than 25mm in length and may be assigned to birth-month groups, but there are four with less clear, only slightly undulating curves. There is a further group of twelve specimens with small short curves. Four of these cannot be placed into a birth-month group, but the other eight have May–June patterns.

The sequential samples in 50 teeth give clear curves that allow the birth season to be interpreted. The evidence suggests that, in Neolithic Çatalhöyük, lamb births peaked in late spring. The pattern is similar to that for wild sheep on the Bozdağ Reserve, 30km away, which give birth in late May (Kaya & Aksoylar 1992), and overall the birth season was later than in modern herds nearby at Küçükköy.

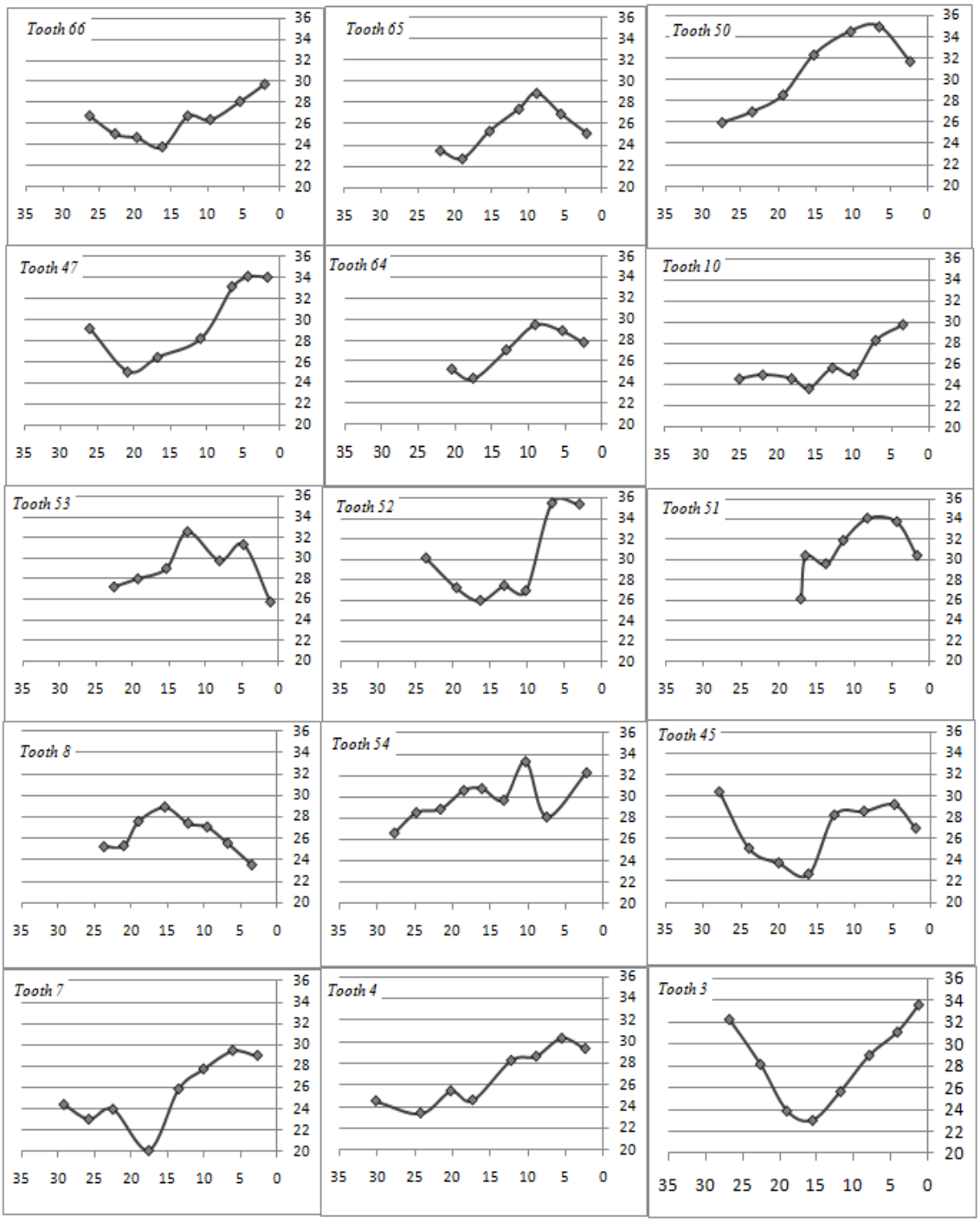


Figure 10.16
Sequential curves of $\delta^{18}O$ values in all second mandibular molars from Catalhoyuk sheep

Y-axis gives oxygen isotope values
X-axis gives distance from the enamel–root junction in mm, and represents a fixed point that is c. 12 months after birth. The result for the enamel formed closest to birth is on the left.

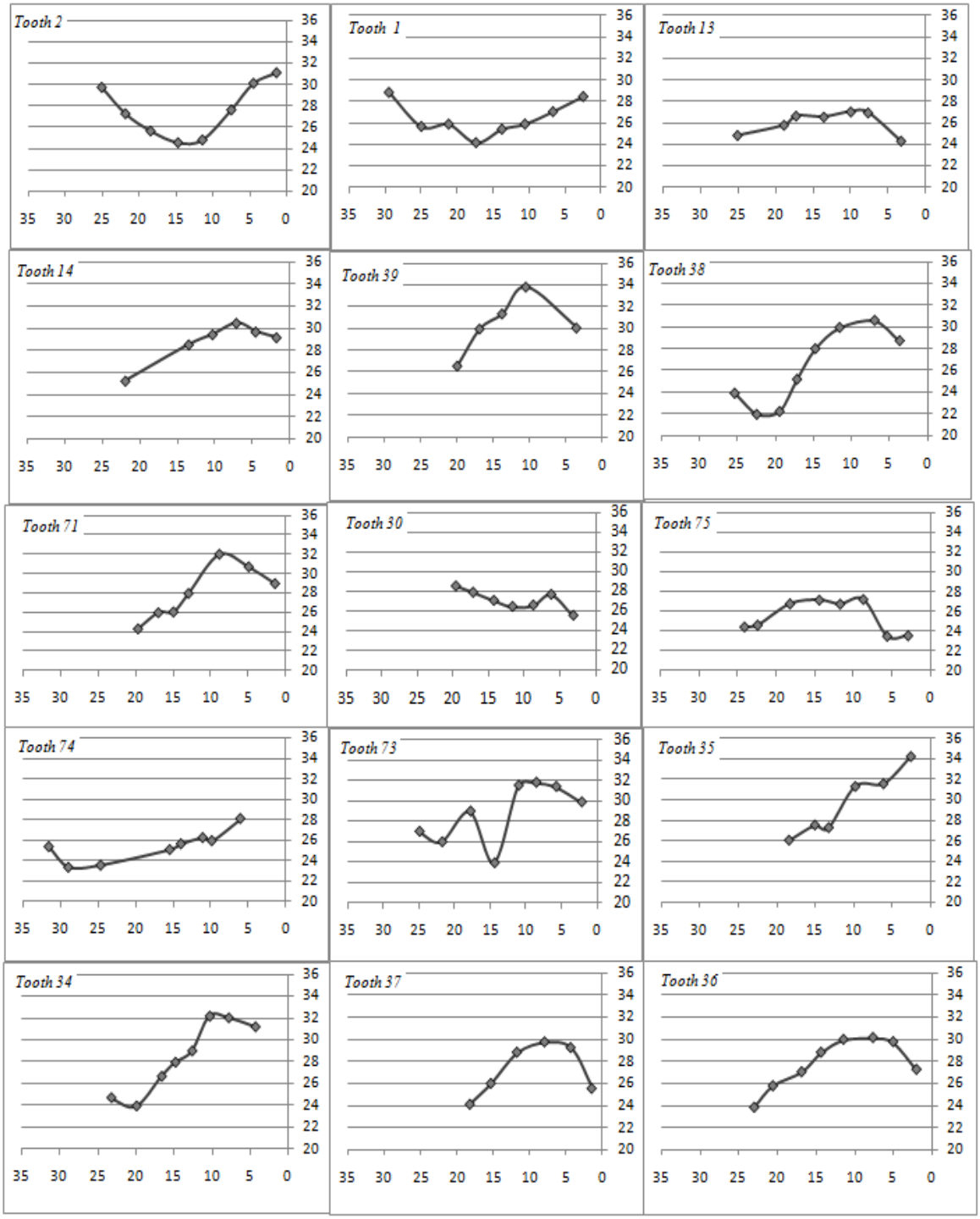


Figure 10.16 cont.

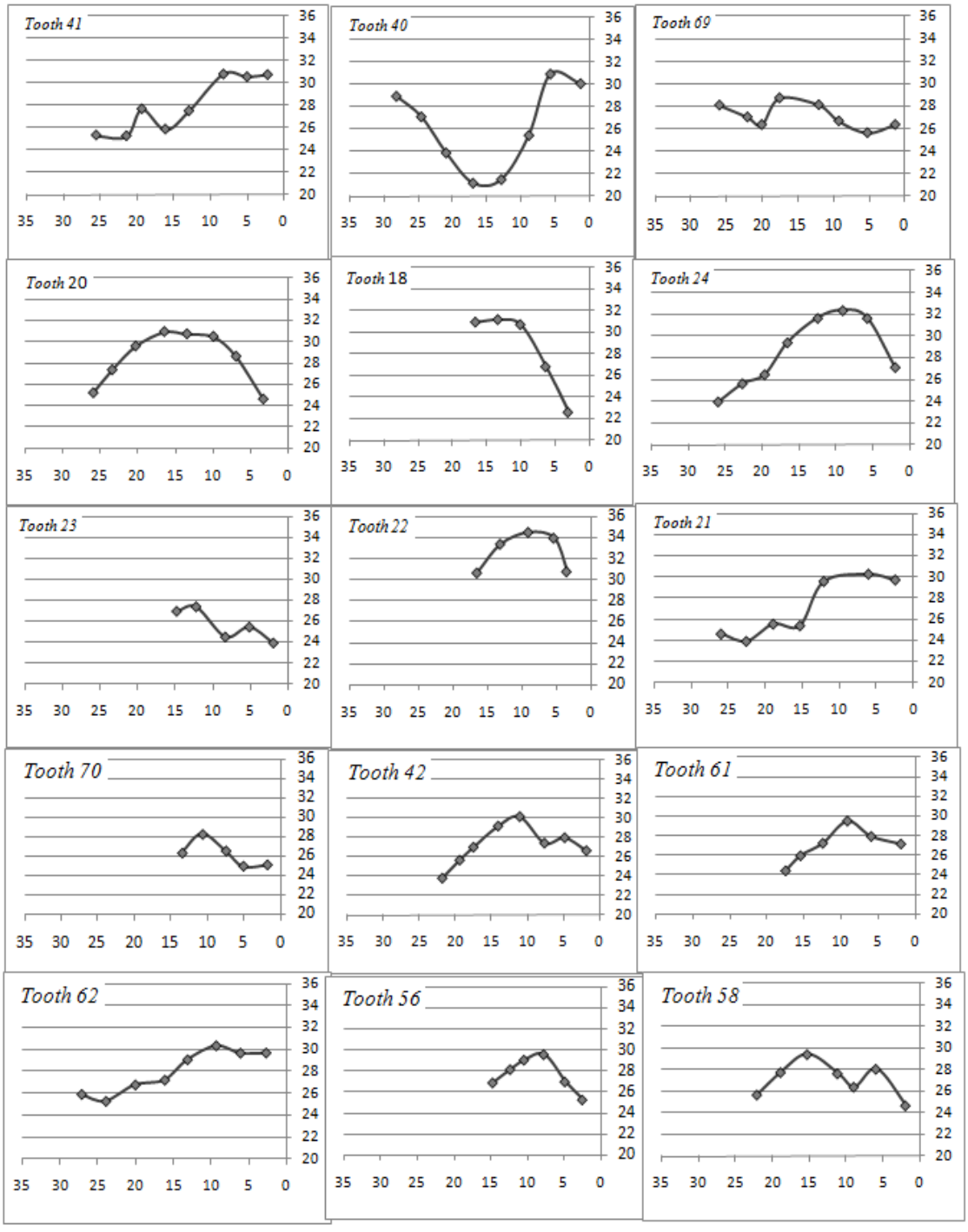


Figure 10.16 cont.

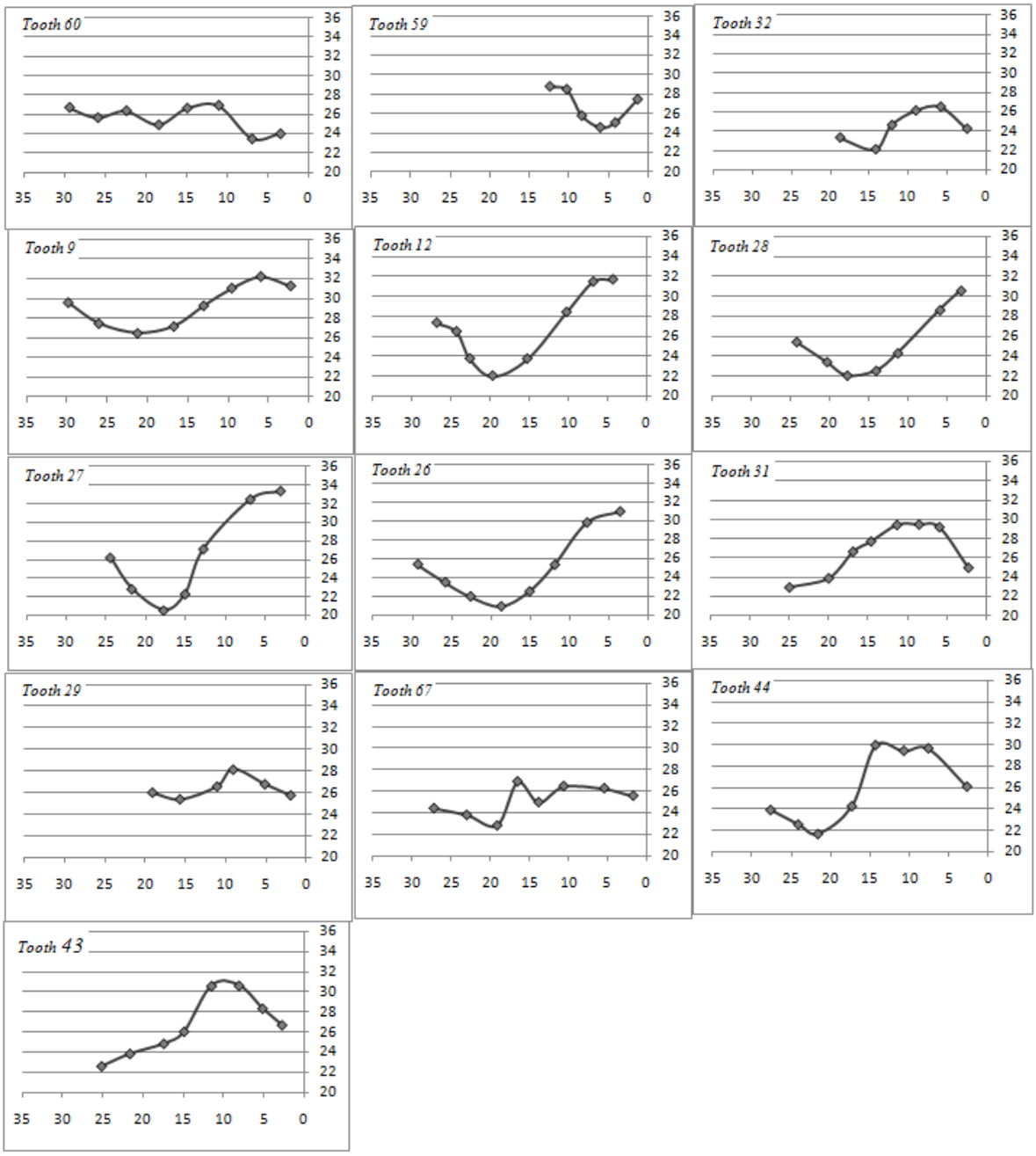


Figure 10.16 cont.

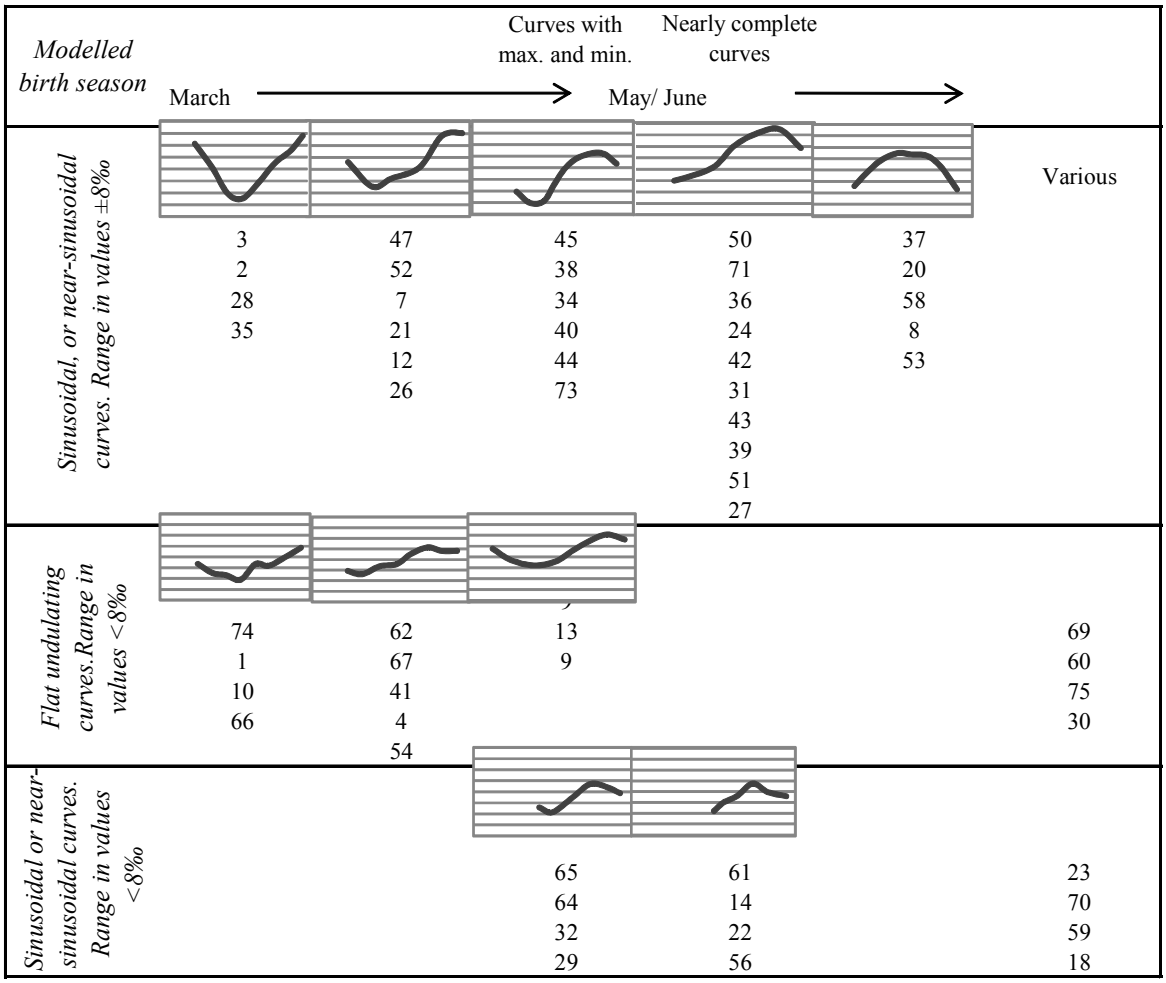


Table 10.8
Archaeological teeth grouped by interpreted birth season, subdivided to show major differences in curve shape within each group

10.3.2.2. Chronological analysis of archaeological data

All chronological groups have examples of births in more than one season (*Figure 10.17*) but between chronological groups the evidence, albeit from a limited sample size, points to changing birth-season patterns. Late births dominate in all groups but there is a marked fall in group 2, coinciding with a rise in early birth percentages. However, in group 3 earlier birth numbers fall again with none in groups 4 and 5. The late births rise rapidly after group 2 and reach their maximum in groups 3 and 4; they maintain high levels until the end of the settlement. If the small samples correctly reflect the population, these changes are particularly interesting.

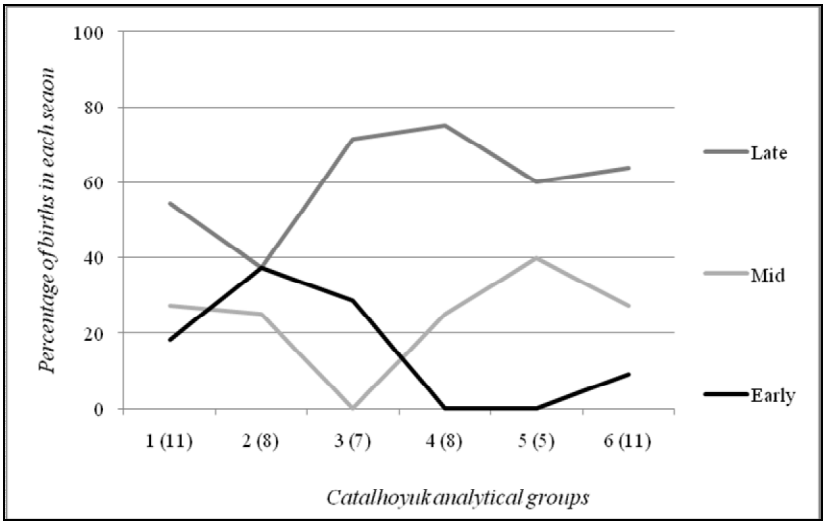


Figure 10.17
Chart showing chronological changes in percentages of births in different seasons, from earlier (left) to later (right). Sample sizes in brackets

10.3.2.3. Spatial analysis of archaeological data by area of excavation

Results from the South Area (28 specimens) are compared to those from other areas (22 specimens) (*Figure 10.18*). There are no significant differences in the birth-season patterns of the sheep from these two spatial groups.

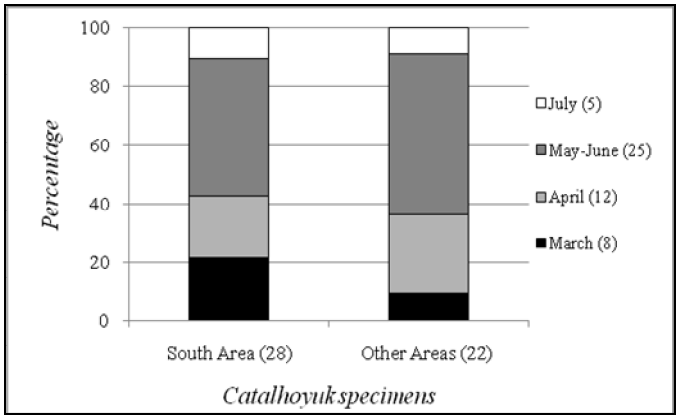


Figure 10.18
Birth months of Çatalhöyük sheep, comparing those from the South Area to other Areas of excavation

10.3.2.4. Spatial analysis of archaeological data by association with building type

Specimens taken from middens associated with the neighbourhood of a long-lived sequence of houses (B65, 56, 44 and 10) are compared to neighbourhoods with buildings with no such sequence (*Figure 10.19*). As with the analysis by area of excavation, there are no significant differences to be observed. In both spatial comparisons, the evidence indicates similarities in the sheep birthing season.

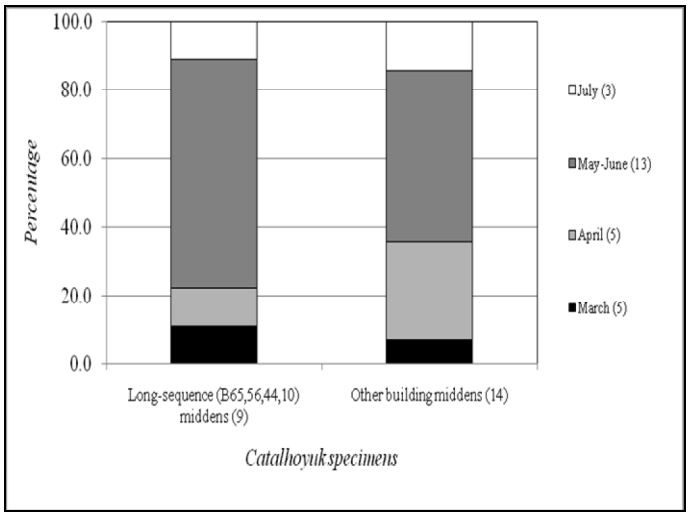


Figure 10.19
Birth months of Çatalhöyük sheep comparing those from one long-lived house sequence to those from other houses

10.4. Movement during the first year

10.4.1. Establishing a model from the modern data

The original intention of this project was to model the effects of altitude on the oxygen isotopic values in summer ingested water through comparison of empirical data from Küçükköy and Bozdağ specimens; the locations were chosen for their geographical proximity. As Bozdağ specimens were not available a different approach is taken (*Table 10.9*).

In discussing the modern data, it was suggested that the degree of depletion in summer $\delta^{18}O$ values is a marker of protection from summer extremes, which might be associated with pasturing in shaded or uphill locations. Maximum $\delta^{18}O$ values that fall below modelled inter-annual variability are modelled to indicate the possible pasturing of Çatalhöyük sheep away from more exposed, lower locations on the plain, fan, sand-ridges and terraces during the summer.

The shape of the curves adds information that might contribute to interpretation of herd movement. The pronounced annual $\delta^{18}O$ curve for Ankara (IAEA/WMO 2006) is generated from data collected in one location, and shows the marked seasonality of central Anatolia (*Figure 10.2*). The sequential sampling of enamel (*Figure 10.14*) from Küçükköy sheep, raised in one location on the central Anatolian plain, also shows marked variability in $\delta^{18}O$ values. Sheep raised in one location throughout their first year may be modelled by full sinusoidal-shaped curves generated from their sequential enamel $\delta^{18}O$ values. Where there are low maximum values, the first year location is modelled as being in more sheltered or uphill locations.

Where herds are moved extensively through lower and higher altitudes during their first year it might be expected that a combination of upland and lowland oxygen isotope signatures would be present in their tooth enamel, and that the resulting curves would not resemble seasonal ones (Bocherens *et al.* 2001; Mashkour *et al.* 2002; Meiggs 2007). The Lakenkhel of northwest Afghanistan describe their vertical transhumance in spring and summer as a permanent springtime (Balıkcı 1990). Vertical movement of herds might serve to dampen summer to such an extent that the resulting curve has very low amplitude, and little evidence of seasonality.

However, curves associated with vertical transhumance might be inseparable from curves derived from water ingested in plants growing in locations where seasonal signatures have

Shape of curve	*Summer $\delta^{18}O$ values*	*Range in $\delta^{18}O$ values*	*Possible explanation*	*Interpretation*
Sinusoidal, or near-sinusoidal	Within or above modelled inter-annual variability	±8‰	Sheep ingesting water exposed to the full effects of hot, arid summers	Sheep raised in hot, arid conditions on the plain, alluvial fan or sand-ridges
Flat undulating	Below inter-annual variability	<8‰	Sheep ingesting water in a range of summer conditions, or ingesting averaged water.	Vertical transhumance of sheep in summer or pasturing near springs fed by ground-water
Sinusoidal or near-sinusoidal	Below inter-annual variability	<8‰	Sheep ingesting water shaded from summer sun with less-evaporative water sources	Sheep raised in stream valleys cutting through the terrace and hillslopes on the edge of the plain

Table 10.9
Model of first year pasturing interpretation based on summer $\delta^{18}O$ values and the shape of the sequential curve of $\delta^{18}O$ values

become mixed and averaged. As a possible satellite camp, Pınarbaşı B, is beside such a karstic spring and only one day walk away from Çatalhöyük, a very flat curve of $\delta^{18}O$ values is modelled as signifying either vertical transhumance or summer herding near karstic springs on the Konya Plain.

10.4.1.1. Summary

1. The marked seasonality in central Anatolia is displayed by clear sinusoidal curves of $\delta^{18}O$ values in monthly meteoric data and in sequential enamel samples from the second mandibular molars of sheep raised in one location in central Anatolia.
2. Çatalhöyük sheep raised in one location, throughout their first year, may be modelled, by full sinusoidal-shaped curves generated from their sequential enamel $\delta^{18}O$ values.
3. Çatalhöyük sheep raised in more sheltered or uphill locations during their first year may be identified by maximum values that fall below modelled inter-annual variability.
4. Çatalhöyük sheep moved as part of vertical transhumance during their first year would not have sinusoidal curves as they move between locations with different ingested water conditions during one season.

5. Çatalhöyük sheep ingesting water where the seasonal input was mixed and averaged would have very flat curves with little evidence of seasonality.

10.4.2. Archaeological interpretation

10.4.2.1. Overview and analysis of data in archaeological specimens

The full results are table in *Appendix 19* and summarised in *Table 10.10*. It is clear that most Çatalhöyük sheep (83.7%) experienced the full range of conditions in one location, and that this location was where maximum $\delta^{18}O$ values fell within the inter-annual variability associated with hotter, more arid summers in more exposed settings at lower altitudes, such as the alluvial fan, marl plain, sand-ridges or low terraces.

Summer location	*Number of specimens*		*Percentage of specimens*
	All	*Most secure*	
Summer vertical transhumance or herding by karstic springs	8	8	9.3
Summer in cooler locations such as shaded valleys or slopes	6	5	7
Summer in exposed places on the plain, fan, sand-ridges or terrace	43	34	83.7

Table 10.10
Summary of the interpretation of herd movement in Çatalhöyük

Nevertheless, 16.3% have maximum $\delta^{18}O$ values below the modelled inter-annual variability. It is interpreted that these sheep spent their first summer in cooler locations such as shaded valleys or north-facing slopes leading up through the terraces and lower hillslopes. Approximately half of this group have undulating, stepped curves leading to higher $\delta^{18}O$ values (*Figure 10.20*). Although there is no modelled modern comparator, it is tentatively suggested that the flatter parts might represent periods of movement uphill through temperature zones – the permanent springtime of the Lakenkhel – and the rising sections represent periods of remaining in one location whilst summer temperatures continue to rise. However, it is also possible that these sheep were raised by karstic springs.

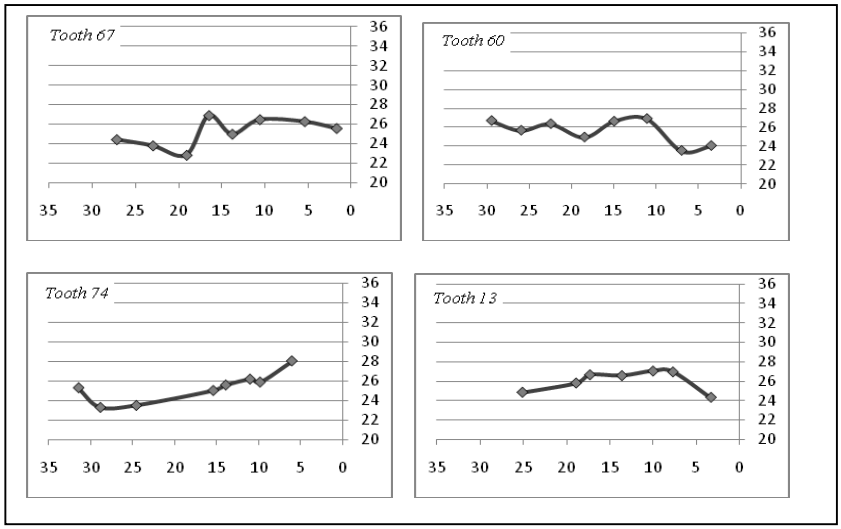


Figure 10.20
Examples of flat, undulating curves with low maximum $\delta^{18}O$ values

10.4.2.2. Chronological analysis of archaeological data

The use of more distant locations for herding in more benign summer conditions varies between phases in a non-linear manner (*Figure 10.21*). In analytical groups 1 and 4 almost all (*c.* 90%) sheep were locally raised during summer, whereas in groups 2, 3 and 5 that percentage dropped to *c.* 60%, with a marked rise in the sheep that were raised in summer

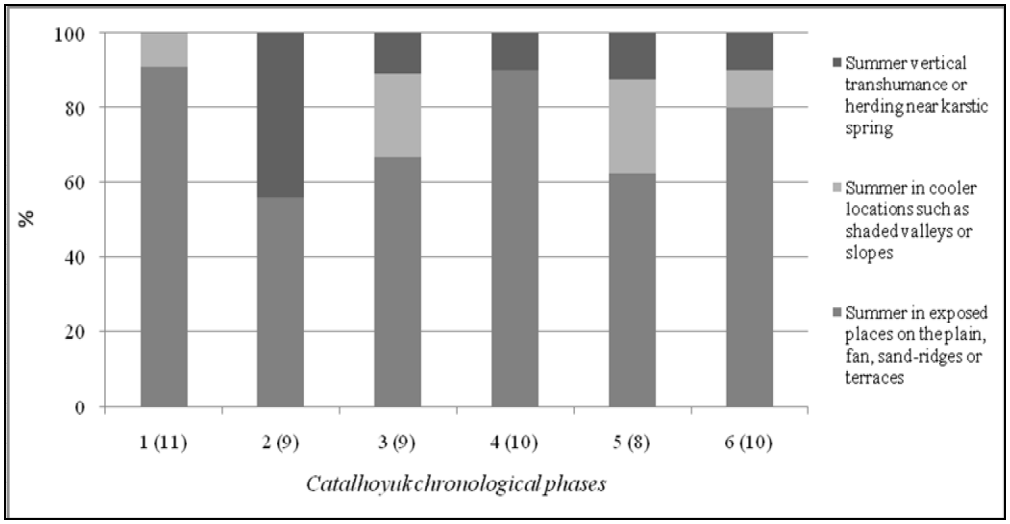


Figure 10.21
Chronology of interpreted herd movement at Çatalhöyük by analytical groups, earliest to the left and latest to the right. Sample size in brackets

locations elsewhere throughout their first year. Group 2 stands out as a period where over 40% sheep were either part of a vertical transhumant herd or that were herded near karstic springs. Once again, the rather small sample size of each group should modify reliance given to the results.

10.4.2.3. Spatial analysis of archaeological data by area of excavation

The results for the summer locations of herding were very similar in all the excavation areas of Çatalhöyük, with little indication of different practices in different parts of the settlement (*Figure 10.22*). The percentage of sheep that were pastured near the settlement on the fan, plain, sand-ridges or terraces in summer is the same across the whole settlement.

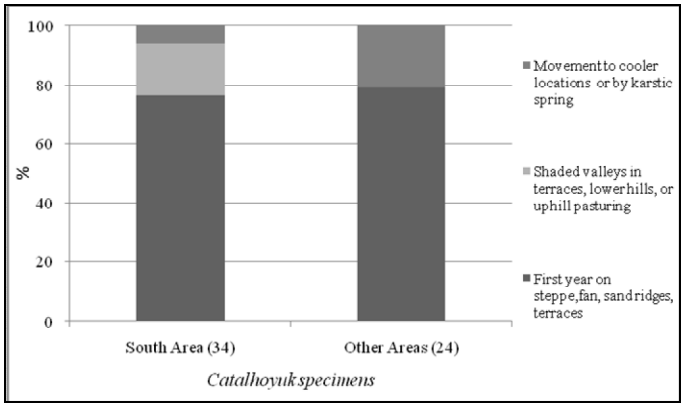


Figure 10.22
Interpreted herd movement by area of excavation at Çatalhöyük

10.4.2.4. Spatial analysis of archaeological data by association with building type

If interpretation of the data is correct, then more sheep (>40%) associated with the long sequence-buildings (B65-56-44-10) neighbourhoods are herded in cooler summer locations than sheep (<25%) associated with other building neighbourhoods (*Figure 10.23*). The difference is largely accounted for by *c.* 10% sheep associated with the long building sequence that might have spent all their first year in another location on the terraces or hillside.

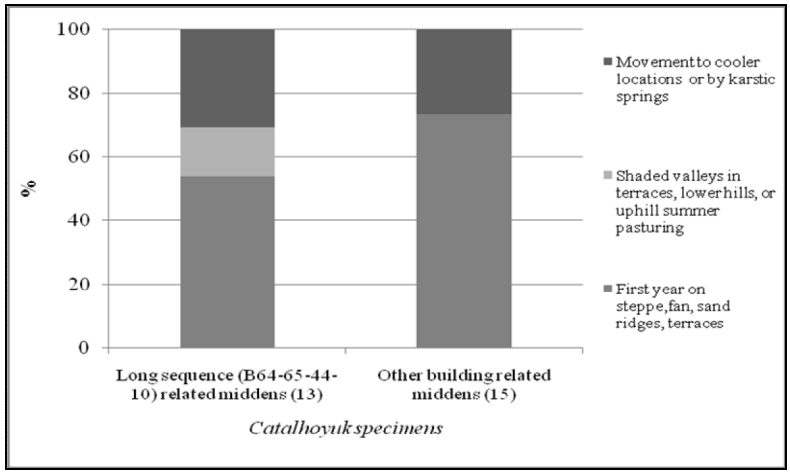


Figure 10.23
Interpreted herd movement by building type at Çatalhöyük

10.5. Conclusion

The test for tooth carbonate diagenesis shows that it is valid to analyse the carbonate component of the archaeological teeth. The curves generated by sequential sampling along the tooth column confirm this absence of diagenesis, as well as satisfactory preparation and analytical procedures. Through comparison of the relevant GNIP data with that from eight modern specimens with known histories, a range of birth season and herd movement practices are modelled.

There are 58 archaeological specimens, with a range in values and a degree of resolution that allow interpretation. The very small sample size gives six analytical groups suitable only for exploring indications of chronological trends, but give two spatial analyses suitable for robust exploration of differences in herding practice by area and by neighbourhood. Seasonal protection offered to sheep is approached through analysis of the conditions in which they were ingesting water, and breeding management is approached through analysis of the timing of birth seasons. The use of, and movement to, pasturing locations that provide sheep with less or greater protection from seasonal weather extremes is approached through combining an analysis of the seasonal conditions of water ingestion with an examination of the annual sequence of seasonal signatures.

With the exception of a few outliers, mean $\delta^{18}O$ values in all specimens fall within the modelled inter-annual variability for central Anatolia. This suggests that most sheep were raised locally. The curves of sequential $\delta^{18}O$ values suggest that late spring was the favoured birth season. The maximum $\delta^{18}O$ values and the shape of the curves of sequential $\delta^{18}O$ values indicate that pasturing throughout the year usually took place near Çatalhöyük on the alluvial fan or on the plain, sand-ridges or terraces within a few days of the settlement. Within each category there are exceptions, indicating some variety and a lack of total uniformity in all tested aspects of herding practice. These are discussed further in *Chapter 12*.Within these generalities, however, certain chronological and spatial patterns emerge.

Consistent minimum $\delta^{18}O$ values suggest that sheep were protected from cold winters throughout the Neolithic occupation. However, towards the end of the settlement, the evidence might suggest that sheep were more exposed to greater winter extremes but to more ameliorated summer conditions. Evidence from the curves of sequential $\delta^{18}O$ values indicates that, after a brief reversal in group 2, a late birth season might have become more established and early births less common.

Spatial analyses by Area produce no clear patterning in birth season, suggesting that the mating and breeding schedule for sheep were managed in similar ways across the settlement. It is possible that the herders shared common practices, or that all sheep were raised as one herd, but there are slight differences between the results for sheep that might have been raised by occupants of the long-lived building- neighbourhoods and by other building-neighbourhood inhabitants. Whilst the birth season for both is the same, the evidence suggests that sheep associated with the long-lived-building neighbourhood were raised in more uniform conditions during their first year. This might have been due to a greater proportion being raised in more benign summer conditions away from the settlement.

CHAPTER 11. DENTAL MICROWEAR RESULTS AND ANALYSIS

The results and analysis of the dental microwear datasets are presented in this chapter in much the same format as for the oxygen isotope datasets in the previous chapter. An additional section presents a component analysis of seasonal plant material eaten by modern sheep in Anatolia. This analysis aims to establish the role of phytoliths and ingested soil in the formation of dental microwear in Anatolian sheep so that additional detail might be added to the model constructed to interpret the archaeological evidence. The analysis of the dental microwear and feed-type datasets provides evidence of dietary regimes before death, and is used to approach research questions on the management of animals brought to slaughter.

11.1. Assessing the data

After sample selection and examination for unusual wear and pathologies, 72 archaeological and 12 modern sheep second mandibular molars were judged to be suitable for DMA. There are 14 more archaeological samples than for oxygen isotope analysis, and, as DMA is non-destructive, it was possible to include specimens from the Selcuk University Bozdağ wild sheep collection in the modern samples. All teeth are in good condition with little abrasion or other post-depositional effects.

The collection strategy for the modern sheep teeth and their pre-death food was described in *Chapter 9*. Dental microwear analysis was carried out on three sheep that died on autumn pasture, although no pasture samples were collected for component analysis. Three straw-rich fodder samples were analysed for their principal components although the microwear analysis on the teeth of associated slaughtered sheep was rejected due to dietary additions of

complex modern supplements. Pre-death diets consisting of young and green pasture plants (hereafter 'green pasture'), of mid-summer, dry and grass-rich pasture (hereafter 'mature pasture'), and of cereal stubble are directly linked to teeth analysed for their dental microwear. The green pasture plants are divided into two groups – one is grass alone, and the other is a mix of low-growing grass and soft dicotyledonous annuals.

11.2. Establishing a model from modern data

The first stage in establishing a model to test the archaeological data assesses the role of phytoliths and soil in the formation of dental microwear. As discussed in detail in *Chapter 8*, soil, ingested with soft foods that have a negligible phytolith component, is known to cause pits (Puech *et al.* 1991*;* Teaford 2007, 121). However, grasses can be rich in phytoliths and can also be ingested with soil; either might cause the striations that are formed on rumination (*Table 8.2*). The results from the plant component analyses are used to generate a series of predictions on the dental microwear associated with these plants in sheep teeth. The predictions compare soil and phytoliths, as the main causes of striation microwear.

11.2.1. Plant component analysis

No. Samples	*Season*	*Feed type*	*Total soil sample*		*Inorganic faction only*		*Total soil sample*	
			Organic %	*Inorganic %*	*Phytolith %*	*Soil %*	*Phytolith %*	*Soil %*
3	April	Young very green grass	89.9	10.1	27.8	72.2	2.2	7.9
6	June	Green pasture grass & forbs	86.3	13.7	20.0	80.0	2.7	11.0
3	August	Dry summer pasture	88.1	11.9	67.1	32.9	10.0	1.9
3	August	Wheat & barley stubble	75.4	24.6	73.8	26.2	18.1	6.4
3	Winter	Wheat straw fodder	93.5	6.5	73.8	26.2	4.8	1.8
3	Winter	Barley straw fodder	92.4	7.6	36.0	64.0	2.8	4.8
3	Winter	Legume straw fodder	93.0	7.0	36.1	63.9	2.5	4.5

Table 11.1

Summary of plant component analyses resulting from loss-on-ignition and phytolith-soil separation

Three samples of each dietary group were collected, and each sub-sampled three times for component analysis. In total seven different categories of plants eaten by sheep were analysed. The full results are in *Appendix 20* and are summarised in *Table 11.1.*

11.2.1.1. Organic and inorganic components

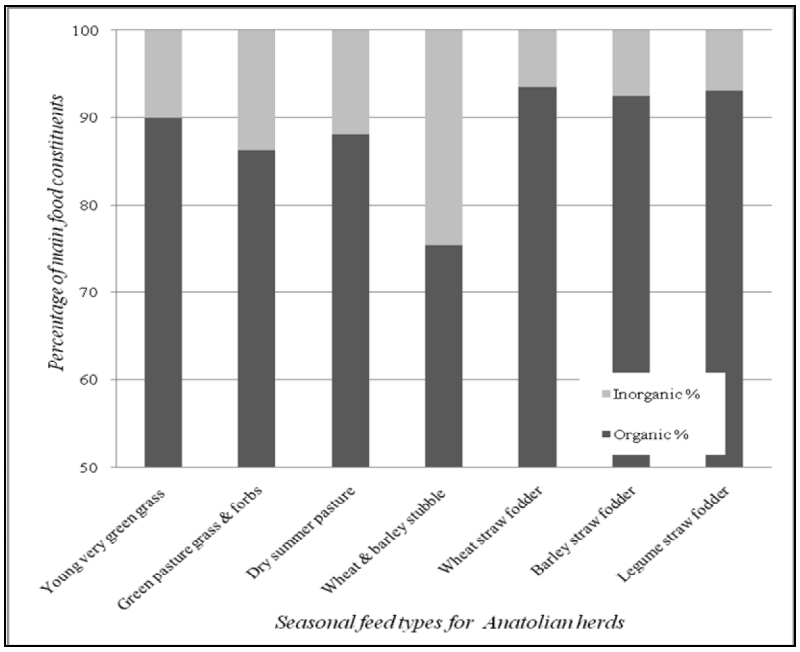


Figure 11.1
Chart showing organic and inorganic components of modern feeds

Loss-on-ignition analysis (*Figure 11.1*) shows that the inorganic component volume is lowest in all fodders, at less than 10%, and is just over 10% in green grasses, forbs, and mid-summer pastures. It is only in wheat and barley stubble that the inorganic component rises markedly, to 25%, probably as cereal-stalk bases are considerably more fibrous than the finer stalks and inflorescences of wild grass hay (Landau *et al.* 2000, 45; Palmer 1998, 4).

11.2.1.2. Phytoliths and soil in the inorganic component

The results of the phytolith and soil analysis of the inorganic component of plants (*Figure 11.2*) show that green pasture plants, whether grass alone or with additional soft forbs, have fewer phytoliths and more soil than both mature grasses and cereal stubble. Phytolith

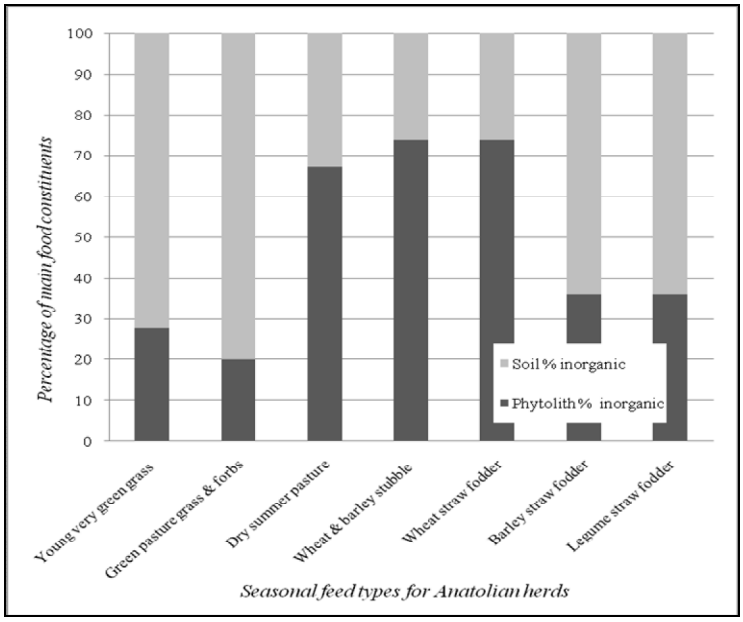


Figure 11.2
Chart showing soil and phytolith percentages in inorganic component of modern feeds

amounts increase as plants mature (Janis *et al.* 2004, 375), and so the high soil percentage in younger plants might solely be a function of their low phytolith content. The first prediction states that, if phytoliths cause dental microwear striations, sheep eating a diet rich in mature grasses or stubble will have more striations on their teeth than those grazing on young pasture. As stubble has a higher total inorganic component, then its phytolith component is proportionally greater, and so, if the first prediction holds true, sheep eating cereal stubble should have the greatest number of dental microwear striations.

Alternatively, the results might indicate that soil is more frequently ingested when there is more rain loosening the soil on low-lying graze, rather than when wind-blown dust settles on higher plant parts in the arid season. The second prediction states that, if wet soil inclusions cause striations, sheep eating a diet rich in green pasture plants will have more striations on their teeth that those eating mature grasses or cereal stubble. Furthermore, the greater volume of phytoliths in stubble should not lead to any differences between the results of all the dry feed types.

The results show that both barley and legume fodders also have low phytolith content, whereas wheat-rich fodder is phytolith-rich. Wheat crops need more irrigation than barley and legumes, and the higher water-throughput increases the size and number of phytoliths (Rosen & Weiner 1994, 131). The third prediction states that, if the first prediction is true, i.e. that phytoliths cause dental microwear striations, then fodder from legumes will have low striation numbers whereas wheat chaff will have high numbers. The fourth prediction states that, if the second prediction is true, i.e. that wet-soil inclusions cause dental microwear striations, then all fodders will produce low numbers of features.

Food type		*Food analysis*		*Predicted number of microwear features*		
		Amount of inorganic component	*Dominant inorganic component*	*If caused by wet soil*	*If caused by dry soil*	*If caused by phytoliths*
Graze	Young very green grass	Low	Grit	Very high pits	Low pits	-
	Green pasture grass and herbs	Low	Grit	Very high pits	Low pits	-
	Dry summer pasture	Low	Phytolith	-	Striations	High striations
	Wheat and barley stubble	Higher	Phytolith	-	Striations	Very high striations
Fodder	Wheat straw	Low	Phytolith	Striations dependent on fodder preparation		High striations
	Barley straw	Low	Grit			Moderate striations
	Legume straw	Low	Grit	Pits dependent on fodder preparation		-

Table 11.2
Summary of feed component analysis with predicted associated microwear

In summary the variables for each diet are the volume of inorganic material and the dominant inorganic component. The predictions suggest that discrimination between diets rich in green pasture plants and those based on cereal stubble grazing is possible.

11.2.2. Dental microwear analysis of modern fodder

The predictions are tested against the dental microwear evidence in modern teeth associated with the plant-type diets. The 12 modern tooth specimens have been categorised according to their diets before the death of the sheep. There are four categories, which cover a range in seasonal pasture and cereal stubble diets. Three of these dietary categories, spring pasture, mid-summer pasture and cereal stubble are directly related to plants collected for their component analysis. There are no examples of sheep feeding on fodder at death, but it might be possible to extrapolate from the other dietary evidence in order to model associated dental microwear. The results are in *Appendix 21* and summarised in *Table 11.3*, and all SEM images used in DMA are in *Appendix 22.*

Food type	*All features*	*Pit %*	*Striation %*	*Pits*								*Striations*							
				Number	*Round*				*Oval*				Number	*Broad*				*Narrow*			
					Number	Length	Breadth	%	Number	Length	Breadth	%		Number	Length	Breadth	%	Number	Length	Breadth	%
Spring pasture (3)	152.33	65.54	34.46	100.33	57.67	9.05	6.27	57.47	42.67	11.41	4.22	42.53	50.67	29.00	13.61	2.23	57.59	21.67	21.10	1.18	42.41
Mid-summer pasture (4)	118.00	34.24	65.76	39.50	16.50	8.53	6.64	40.03	23.00	9.21	4.00	59.47	78.50	31.50	13.16	24.87	48.35	47.00	24.51	3.12	51.65
Late pasture (3)	98.67	21.27	78.73	21.67	14.00	7.99	5.79	64.22	7.67	8.91	3.48	35.78	77.00	17.00	16.29	2.28	19.48	60.00	31.83	1.31	80.52
Cereal stubble (1)	96.00	28.13	71.88	27.00	19.00	9.35	6.55	70.37	8.00	12.34	4.99	29.63	69.00	6.00	17.75	2.56	8.70	63.00	27.21	0.99	91.30

Table 11.3
Summary of dental microwear analysis of modern sheep teeth, grouped by diet before death

11.2.2.1. Total number of features

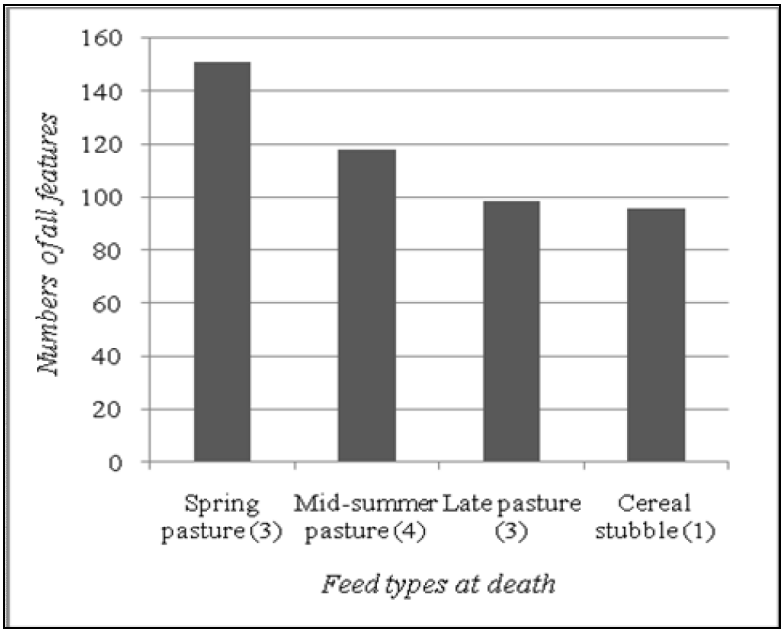


Figure 11.3
Total number of microwear features in modern specimens, grouped by diet

There is a clear decline in the total dental microwear feature numbers, from those associated with green pasture diets, to mid-summer diets, to late pasture and cereal-stubble diets (*Figure 11.3*). This trend is the opposite to the one seen in the phytolith percentages shown by component analysis of green pasture plants, mature pasture plants, and cereal stubble. As green pasture diets have less phytolith content, but more soil, it suggests that ingested soil rather than phytolith content is the more important contributor to dental microwear. The cereal stubble, despite the high volume of phytolith-rich inorganic component shown in the plant analysis, produces low striation numbers, suggesting that phytolith content is a lesser contributor to dental microwear. Thus the first prediction is rejected; phytoliths are not the prime contributor to the amount of microwear in Anatolian sheep.

As the mid-summer and late pastures and the cereal-stubble diets produce low feature numbers, it suggests that, in Anatolia, dry dust does not contribute to microwear as much as

wet soil, that has been associated with the green pasture diets. The second prediction holds true; wet ingested soil causes more features than dry dust.

11.2.2.2. Pit-to-striation ratio

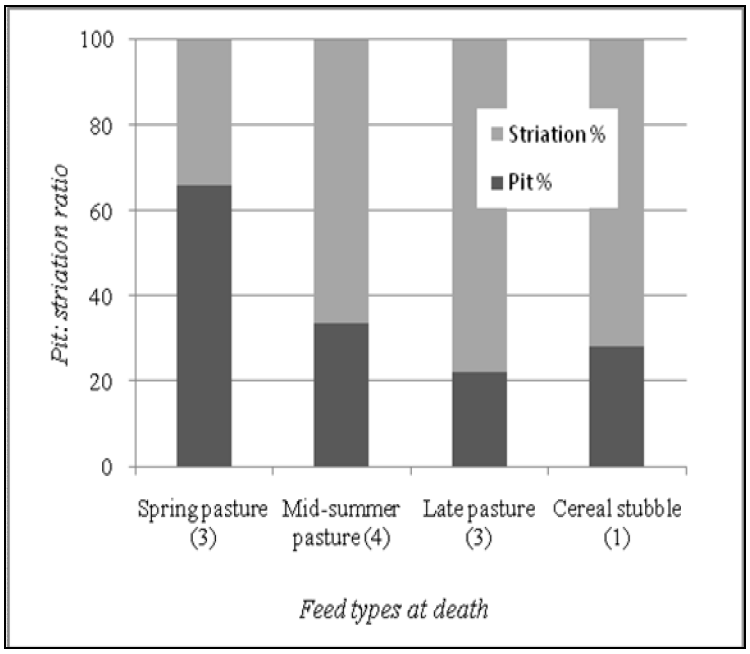


Figure 11.4
Pit-to-striation ratio in all modern specimens, grouped by diet

Two-feature analysis separates pits, associated with plucking soft food and tugging on leafy browse, from striations, associated with rumination on the fibrous chaff, leaves and stalks of wild, pasture grasses and domestic, cereal plants (*Figure 11.4*). Overall, wet soil is the main cause of all microwear features, the two-feature analysis determines whether the diets, dirty or clean, are grass-rich or not, and whether wet soil causes both striations and pits.

The results show that the pit-to-striation ratio is highest in early spring. At this time, young low-growing forbs, such as clover, are chosen by sheep, alongside soft and new grass shoots (Grant *et al.* 1995, 992; Papachristou 1997, 88); both would be plucked and resultant microwear features are likely to be pits. The fall in the pit-to-striation ratio throughout the summer is consistent with ruminating on increasingly fibrous, cellulose-rich diets as grasses

mature. The rise in phytoliths, measured by loss-on-ignition, is consistent with increasing striation numbers. Despite the fall in the pit-to-striation ratio in later pastures and cereal stubble, there is a fall in overall feature numbers, showing that soil causes both striations and pits.

11.2.2.3. Summary

The sample sizes in this modern comparator are very small and might be considered unsafe when establishing the main contributors to microwear formation. However, the collected plants are closely connected to the sheep diets before death in three key categories. In addition, the low feature numbers associated with late pasture diets are consistent with the finding that wet ingested soil causes more features than dry dust or phytoliths. Furthermore, the results are consistent with Mainland's (2003) findings for the causes of dental microwear in sheep.

Although an enhanced modern comparator would be desirable, the evidence shows enough consistency to analyse the archaeological data on the basis of wet soil being the greater contributor to striation and pit dental microwear. However, all mature pasture grasses and cereal stubble have similar phytolith content and similar dental microwear signatures (both total feature numbers and low pit-to-striation ratios); therefore it is not possible to discriminate between these diets. The third and fourth predictions cannot be pursued, as the fodder mix is unknown, and produces equifinalities that cannot be resolved.

Before the evidence from these datasets is used to model archaeological data, the evidence is integrated and tested against that from published datasets.

11.3. Integrating modern Anatolian evidence with published databases

11.3.1. Assessing the compatibility of datasets

The data from the Anatolian sheep can be integrated with ungulate-diet data in published databases. Selected published data are restricted to microwear analyses of second molars under scanning electron microscope. The data include: ten browsing and eight grazing ungulate species from Solounias *et al*.'s (2000) database; sheep that have been grazing, and eating hay or leafy fodder (Mainland 1998b); and two groups of archaeological wild sheep and two of wild goats (Rivals & Deniaux 2003). The sample size of the dietary groups ranges from four to twenty-five. As researchers have quantified microwear in areas of different dimensions, all results, including the Anatolian sheep, have been adjusted so that results represent quantified microwear in a one millimetre square (*Appendix 23*).

There are three problems in integrating Anatolian sheep data with specimens from published databases. Firstly, inter-species enamel differences might affect the microwear signature (Maas 1991). Secondly, differences in the magnification used to observe and capture images might affect results (Grine *et al*. 2002), although Mainland's use of x640 magnification does not vary greatly from x500 used in capturing all other images. The third, and greatest, problem lies in inter-recorder differences (Grine *et al.* 2002), and is discussed below.

The x-axis of the chart (*Figure 11.5*) represents the '1-feature' analysis of dental microwear total features. It is immediately apparent that all Anatolian sheep fall to the right of the chart, having more features than groups from other published databases. The y-axis gives the '2-feature' analysis of the pit-to-striation ratio. Here there is a very close match, identifying Anatolian grazers with all other grazers by low pit percentage. The spring- pastured Anatolian sheep, browsing on soft grasses and forbs, have a higher pit percentage, matching those of other browsers.

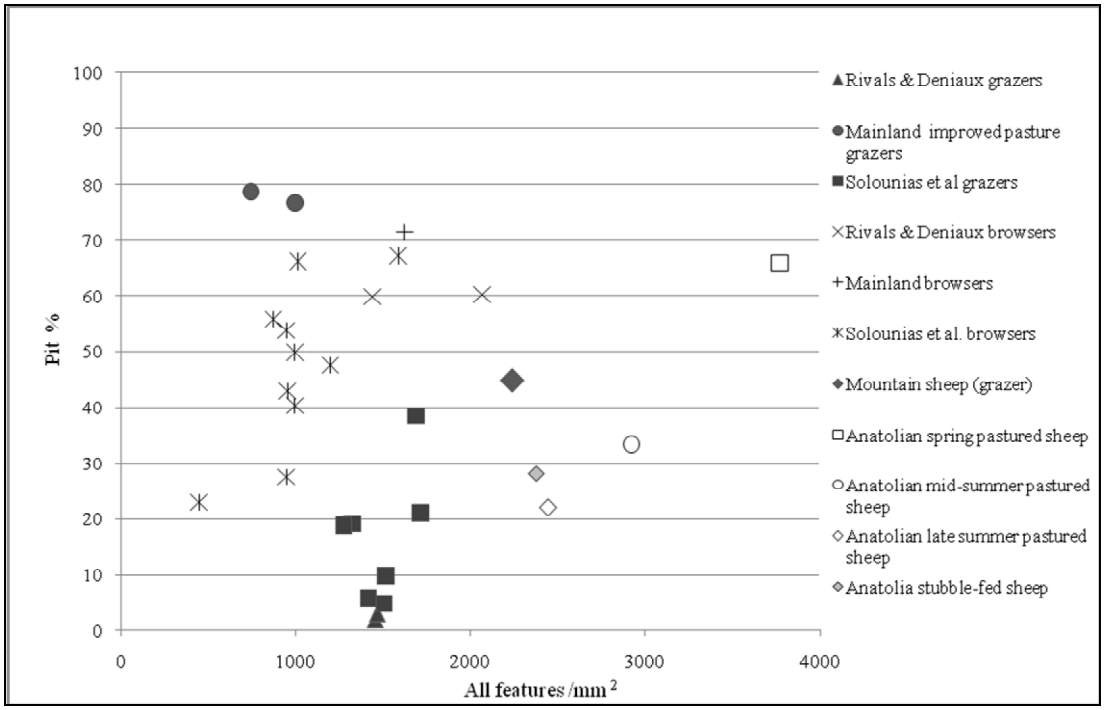


Figure 11.5
Chart integrating published data with modern Anatolian sheep data, plotting all features against the pit percentage

The Anatolian sheep have more dental microwear features than ungulates in the published database, but there is no difference in the dispersion of feature types by primary dietary differences between browsers and grazers. There are two possible reasons for this pattern. The first is recording error, where there is over-counting of features without distortion of feature types. The second possibility is that Anatolian sheep are always more exposed to ingested soil than the ungulates in the published databases. There is no reason to suppose the second possibility is true; Mainland's sheep are from north Europe where pastures are likely to be wetter and muddier, most of Solounias' ungulates are from the African savannah which is likely to be very dusty, and Rivals and Deniaux (2005) worked in the Pyrenean palaeoenvironment which they consider to have been arid. No pattern based on area or climate difference emerges, and nor does one based on husbandry practices. Mainland's sheep were raised under modern farming techniques, the Anatolian sheep were raised by relatively traditional methods, and the other ungulates were wild.

In conclusion over-counting of features, without distortion of feature types, is the best explanation for the differences between the microwear signatures in Anatolian sheep and other published material. With this understanding, it is possible to use the published comparative data alongside the Anatolian data; however, comparison of absolute numbers should include consideration of recorder differences. The modern sheep evidence acts as an interpretive bridge between published evidence in other ungulates and the archaeological specimens which are all identified as sheep teeth.

11.3.2. '5-feature' analysis, using published interpretation

Published interpretations of dental microwear associated with a range of ungulate diets argue that striation breadth, and pit size and shape, can be statistically related to dietary types, although the underlying reasons have not been established. It is not certain what causes striations of different widths. As sheep are the only species studied here it is possible to discount effects arising from inter-species enamel differences. As the evidence points to ingested soil, rather than phytoliths, being the main cause of striations, it might seem that soil particle size determines striation width. However, in savannah regions, narrow striations are associated with C3 grazers and wide striations with C4 grazers, although this has not been tested for co-varying differences in soil ingestion (Merceron *et al.* 2004a, b; 2005; Semprebon *et al.* 2004; Solounias & Semprebon 2002). Mainland's (2003) dung analysis, pointing to soil ingestion, is based in northern Europe where there are only C3 plants, and so cannot resolve the different interpretations.

Differences in the shape and size of pits have been shown to discriminate between soft-food diets. Plucking soft food produces small round pits, whilst tugging tough, woody food causes larger, irregular or oval pits (Mainland 2001, 84; Merceron *et al*. 2004a, 129). A '5-feature' analysis, using pit and striation dimensions, is carried out in this thesis, but with the proviso that explanations for any differences rely on published interpretation, and have not been tested with the modern comparator.

11.3.3. Modelling all comparative data

The contribution that dental microwear analysis might make to this research is greater as a result of the modern comparative data, and is summarised in *Table 11.4*.

- Observer error reduces the analytical tools that may be used, as does the small sample sizes for the dietary regimes of Anatolian sheep. Where appropriate the statistical significance of difference between groups will be assessed using the Mann-Whitney-U non-parametric test.
- The comparison between plant components and associated dental microwear establishes the primacy of wet, ingested soil in the formation of pit and striation microwear in Anatolian sheep.
- Plant component analysis establishes the low phytolith content of early spring young grass shoots and low-growing green forbs. This produces low striation and high pit numbers because the sheep are, in fact, browsing on soft material that does not need rumination.
- Pit percentages of <35% indicate diets of mature grasses and cereals.
- Pit percentages of >35% indicate diets on soft, leafy browse or new growth of grasses and forbs.
- Where pit percentages are >35%, high all-feature numbers indicate diets of new grass and forb growth where wet soil is also ingested. Low all-feature numbers indicate diets on soft leafy browse either as fodder or from trees and shrubs growing above ground level.
- Where pit percentages are <35%, high all-feature numbers indicate diets of mature, winter pasture, where wet soil is also ingested. Low all-feature numbers indicate diets on dry grasses and stubble.
- Round and oval pits are signatures, respectively, of plucked, soft diets and tugged, soft diets.
- Narrow striations and broad striations might be microwear signatures, respectively, of diets rich in C3 and C4 grasses, but this evidence will be confined to interpretive discussion.
- Principal component analysis (PCA) assesses the contributory relationship between all the feature types and the diet.

Table 11.4
Summary of the contribution that dental microwear analysis, as enhanced by modern data, might make to elucidating domestic sheep diets before death

Table 11.5 re-presents *Table 8.2* in light of the evidence from the modern Anatolian diet and dental microwear study. In this thesis, based on the evidence, both striations and pits are associated with grit ingestion, rather than phytolith content of the ingested plants. In addition, wet soil is found to cause more features than dry dust.

Plant group		*Pits*		*Striations*	
		Small round	Large irregular	Narrow	Broad
Monocotyledonous	Young grass	**X**			
	Mature C3 grasses			x	
	Mature C4 grasses				x
	Hay fodder			x/**X**	
	Cereal stubble			x	
	Cereal fodder			x/**X**	
	Reed shoots			**X**	
Dicotyledonous	Young pasture forbs	**X**			
	Field edge weeds	**X**			
	Fallow crops	**X**			
	Legume straw	x/**X**			
	Weed fodder	x			
	Leafy browse		x		
X high numbers (wet soil) x low numbers (dry dust)					

Table 11.5
Final model of the use of dental microwear in the interpretation of dietary regimes in archaeological sheep before death

11.4. Interpretation of the archaeological data

The archaeological data (*Appendix 24*) is first compared to the modern data, where the distribution of data in the whole assemblage is discussed in light of the model constructed above. A broad temporal over-view follows, identifying any overarching patterns, and any chronological groupings that may emerge. The data is then divided into the chronological and spatial groups outlined in *Chapter 9* and used in *Chapter 10*, and emerging differences between the groups tested and discussed. Throughout, outliers are identified for later consideration in *Chapter 12*. SEM images of the area of wear captured for dental microwear analysis in all archaeological teeth is to be found in *Appendix 22*.

11.4.2. Comparison to modern data

Figure 11.6 integrates and displays modern and archaeological data, using a '1-feature' to '2-feature' bivariate plot. The archaeological data are individually recorded as grey squares, and the modern data are displayed by field outlines created from their data-clusters, as seen in *Figure 11.5*.

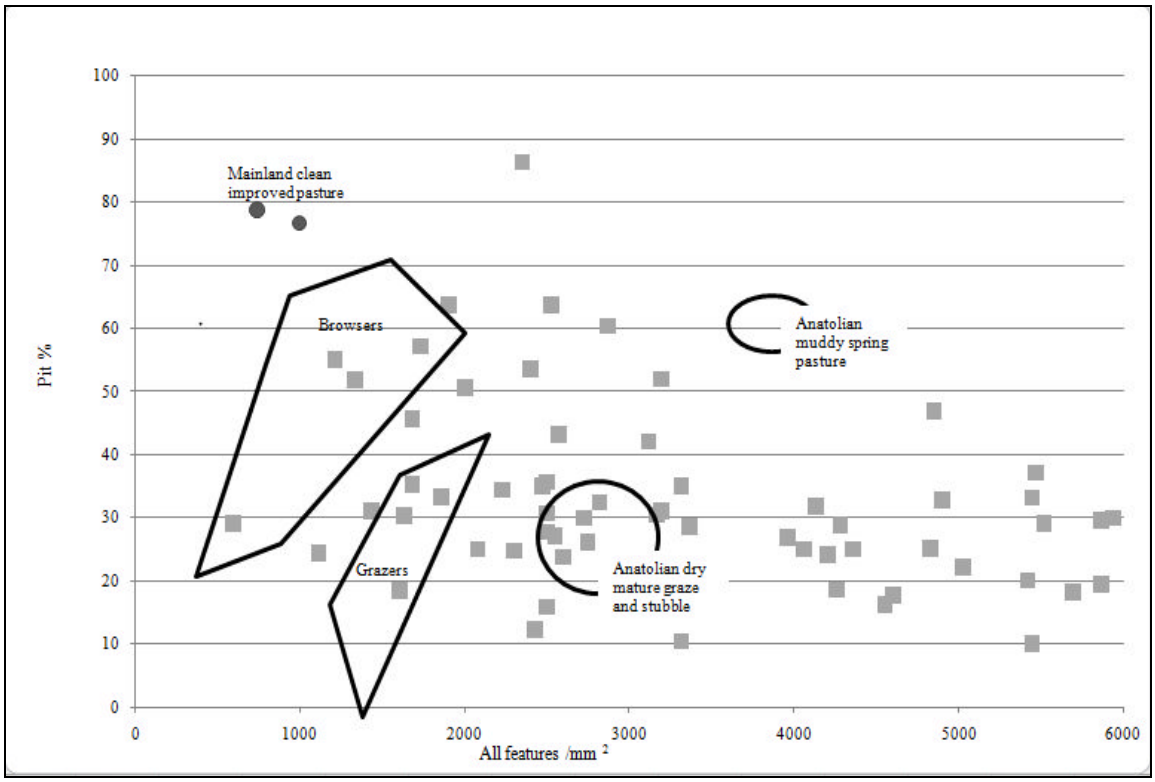


Figure 11.6
Chart comparing archaeological data (grey squares) with modern data (black field outlines)

The '1-feature' count of all microwear features in each tooth specimen, on the x-axis, shows a wide range in feature numbers. Approximately one third of them are within the same range as published modern data, one third similar to Anatolian sheep data, and one third are even higher. The range suggests that over-counting by the recorder is not the only explanation for the high numbers, particularly as the Anatolian features were counted by the same recorder. As overall numbers, in striations as well as pits, have been associated with wet soil intake in the modern comparator, the interpretation is that Çatalhöyük sheep were feeding on diets that ranged from being clean and dry to very dirty and wet.

The 2-feature analysis, on the y-axis, shows that the archaeological data fall into two groups (this is more clearly seen in *Figure 11.8*). One group, on the top left of the chart, has a high pit-to-striation ratio, where the pit percentage is >35–40%. The other group, right across the lower section of the chart, has a pit-to-striation ratio <35–40%. The two groups are consistent with those seen in published work, which divide ungulate feeding into two primary groups of browsers and grazers. The archaeological specimens in the browser group (high pit percentage) have less overall feature numbers than the modern Anatolian browsers. The interpretation is that archaeological browse diets were relatively clean and dry.

The archaeological specimens from Çatalhöyük may be understood within the evidence in the published databases and also in modern Anatolian sheep. Sheep are known to be preferential grazers which only browse on green pasture plants, or when restricted to fodder. It is concluded that the feeding behaviour of archaeological sheep may be understood by analogy to modern animals. However, the archaeological browsers have lower overall feature numbers which can be interpreted as their having ingested little wet soil with their browse.

11.4.3. Overview of Çatalhöyük sheep diet

The box-plots of microwear categories (*Figure 11.7*) provide a more detailed examination of the dental microwear distribution in the whole Çatalhöyük assemblage. The box-plots show that the most commonly eaten diets were fibrous and needed rumination. There was minimal input from soft diets that produce pits in sheep teeth. Principal component analysis (PCA) of the contributory relationship between all pit types and all striation types confirms the dominance of narrow striations in Çatalhöyük microwear signatures (*Table 11.6*).

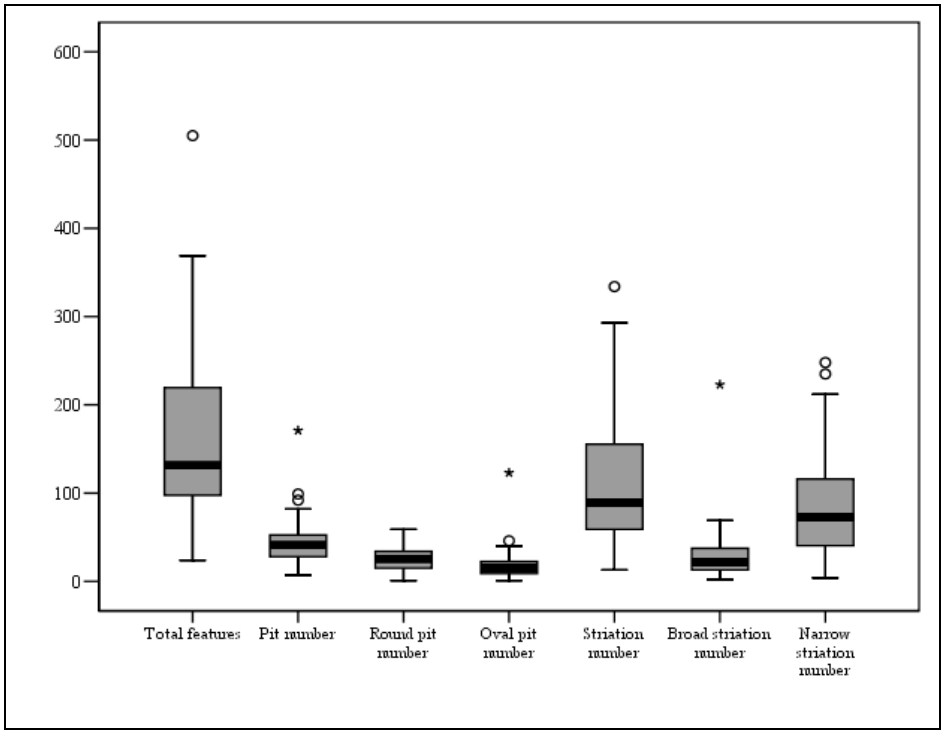


Figure 11.7
Box-plots showing the distribution of dental microwear features recorded in all Çatalhöyük specimens. The x-axis shows each dental microwear category examined, the y-axis shows the number of features.

(*The black bar across each box gives the median value, the grey box represents the interquartile range, the extended vertical lines add the first and fourth quartiles, and circles and stars represent outliers*)

	Component		
	1	2	3
Round pit number	.019	.076	.951
Oval pit number	.024	.256	.339
Broad striation number	.130	.805	-.759
Narrow striation number	.929	-.527	-.032

Table 11.6
Summary of principal component analysis of all dental microwear features in the archaeological specimens

The bivariate plot of the archaeological specimens (*Figure 11.8*) is interpreted using the modelled microwear evidence, where diets with >35% pits are interpreted as soft, dicotyledenous diets and those with <35% pits as fibrous, monocotyledenous diets. With one exception the soft diets cluster together and have <150 total features; this cut-off, marked

with a vertical line, is also used to separate clean and dirty grass-rich diets. It is an arbitary division of what is clearly a continuum of clean to dirty diets, but as it is consistent with the soft food clustering, it is a useful device for interpretation and discussion.

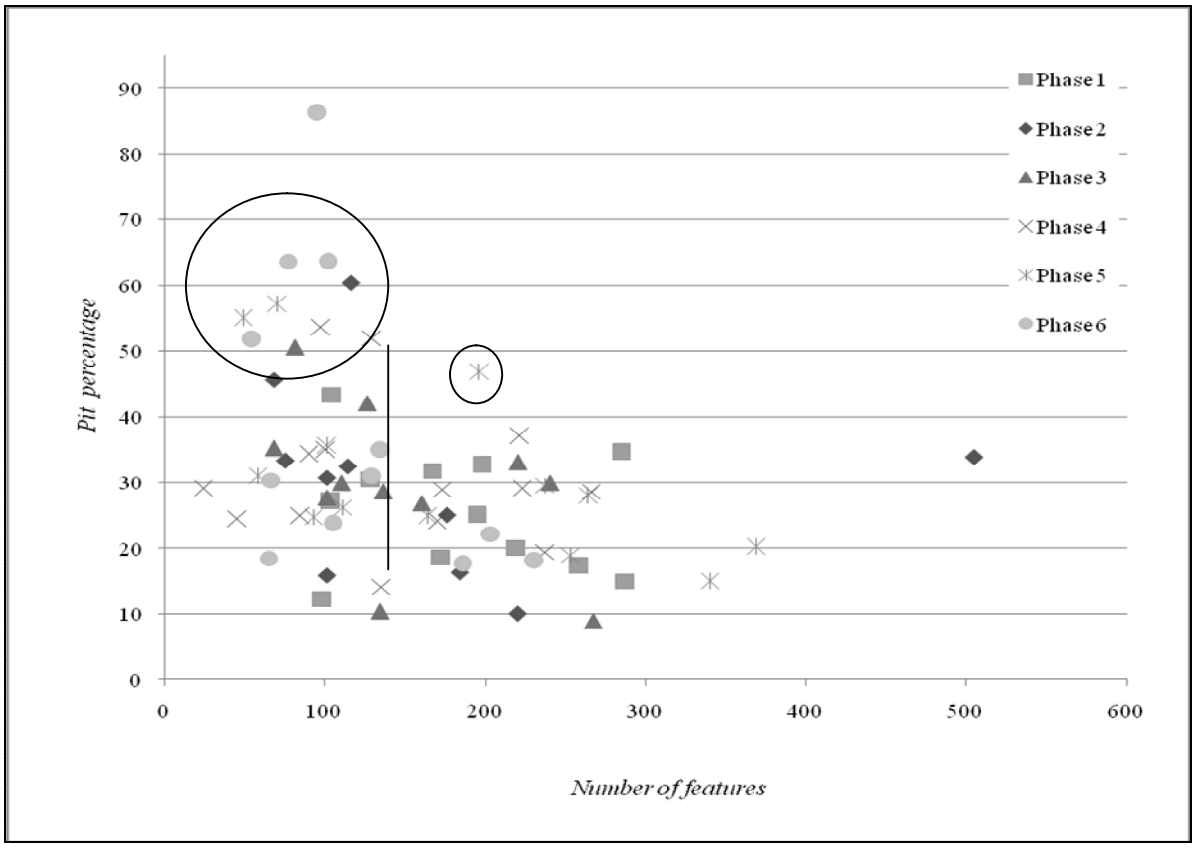


Figure 11.8

Bivariate plot of all Çatalhöyük specimens (72), plotting the number of all features against the pit percentage. The large circle indicates the group of clean, soft diet signatures, the small circle indicates the dirty, soft diet signature, and the vertical line separates clean (to the left) and dirty(to the right) grass-rich dietary microwear signatures

There are 12 tightly clustered individuals with microwear signatures associated with clean, soft diets, and one with a dirtier soft diet. The remaining 60 sheep died having had grass-rich diets divided into cleaner and dirtier groups. In addition there are three outliers; one indicates a soft, but very dirty diet, one an extremely soft diet, and the third a very dirty grass-rich diet.

The wide range in striation-producing diets confirms that the range in overall feature numbers is related to the soil ingestion levels in grass-rich diets. Grass-rich diets include seasonally mature grasses, hay fodder, cereal stubble or cereal fodder. Where striation numbers are high, higher wet-soil ingestion is indicated; this can be associated with winter graze in muddy pastures, rather than arid, summer, stubble graze.

The bivariate analyses of broad and narrow striations (*Figure 11.9)* shows clear linearity, with no evidence of variation in the type of fibrous diet, other than in the amount of ingested soil. Broad striation numbers remain low, indicating that the dietary contribution that caused them was constant, but not important. There are very few C4 plants in Anatolia – in the Çatalhöyük assemblage most of those are identified as halophytic non-grasses, with only one perennial steppe grass, *Aeluropus* sp. (Pearson *et al.* 2007). In Çatalhöyük sheep, given the covariance of broad and narrow striations, it is very possible that broad striations are part of the natural variability in striation widths associated with grassy diets.

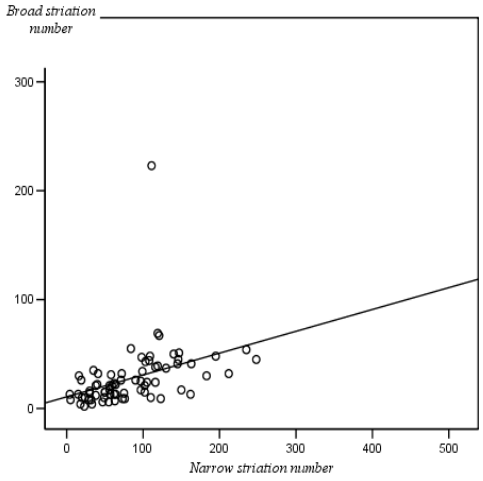


Figure 11.9
Bivariate plot of all archaeological specimens, plotting narrow against broad striations

The narrow range in the pit-producing diets (*Figure 11.7*) confirms that soil ingestion was very low in browse diets. It can be inferred from the low numbers of sheep feeding on browse that few had access to any soft food material before death. It is worth recalling at this

point that browse diets might be associated with early spring new grass and forb growth as well as with soft, dicotyledonous, leafy browse. However, as the soil ingestion in the browse diets is low (*Figure 11.8*), the limited browse access they did have was to dry, clean browse rather than to new shoots of grass and forbs where wet-soil ingestion would have been higher.

The bivariate analysis of round to oval pits (*Figure 11.10*) shows no linear relationship; instead, the modest increase in round pits is unmatched by an increase in oval pit numbers. Round pits are associated with plucked food, which might be legume fodder or weeds grazed or given as fodder. Oval pits are associated with woody, browse diets. Whilst these two diets remain a small, but equal and constant part of the diet of Çatalhöyük sheep before death, access to them was not inter-related.

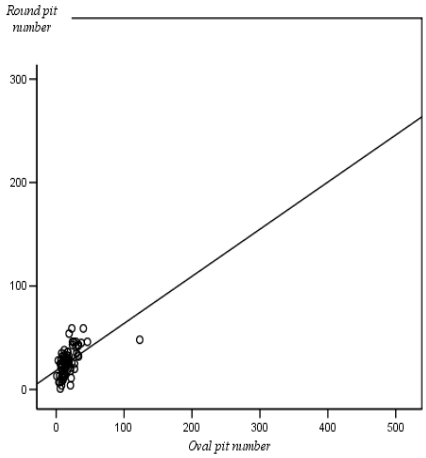


Figure 11.10
Bivariate plot of all archaeological specimens, plotting small round pits against larger oval pits

On closer examination of the twelve individuals with browse dental microwear signatures (*Figure 11.11*), there is still no apparent patterning between oval and round pit numbers. However the round-pit percentages separate into two groups, both with varying amounts of ingested grit contributing to total feature numbers. One group has a very high round pit

percentage, suggesting a diet that was very rich in plucked, soft foods. The other group, with more oval pits, had diets of soft food that needed a little more tugging. In the absence of an extensive modern comparator little more can be said of this small group of browsers.

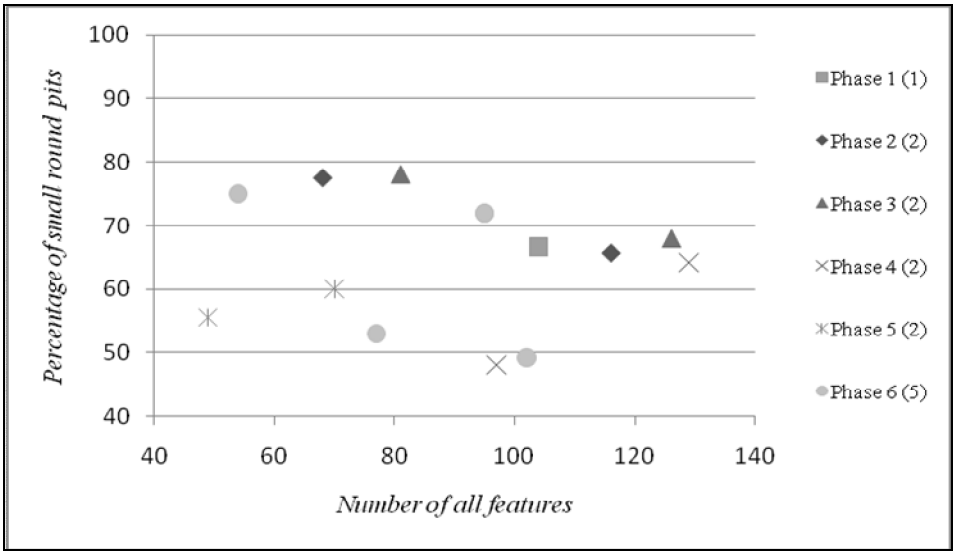


Figure 11.11
Bivariate plot of archaeological specimens in the clean, soft browse group, plotting the small, round pit percentage against the number of all features

In sum, the evidence suggests that sheep dietary resources at Çatalhöyük were almost completely based on grasses and possibly cereals. These diets varied considerably in how much soil, and in particular wet soil, was ingested at the same time. The dryer, cleaner dietary material could have been mature pasture grass, cereal stubble, foddered hay or cereal by-product fodder. The dirtier end of the spectrum is most likely to have been winter pasture grass. The few sheep that died after browsing were eating dry, browse material that was plucked rather than tugged. Such browse might include field-edge weeds, fallow plants or legume by-products, either grazed or collected for fodder when dry and mature. At the time of death there is almost no evidence of Çatalhöyük sheep pasturing or foddering on green pasture plants, green field-edge or fallow weeds, or on leafy browse.

11.4.4. Chronological overview

Figure 11.12 displays the data in a broad archaeological sweep, using the sequence outlined in *Appendix 11,* and used in *Chapter 10*.

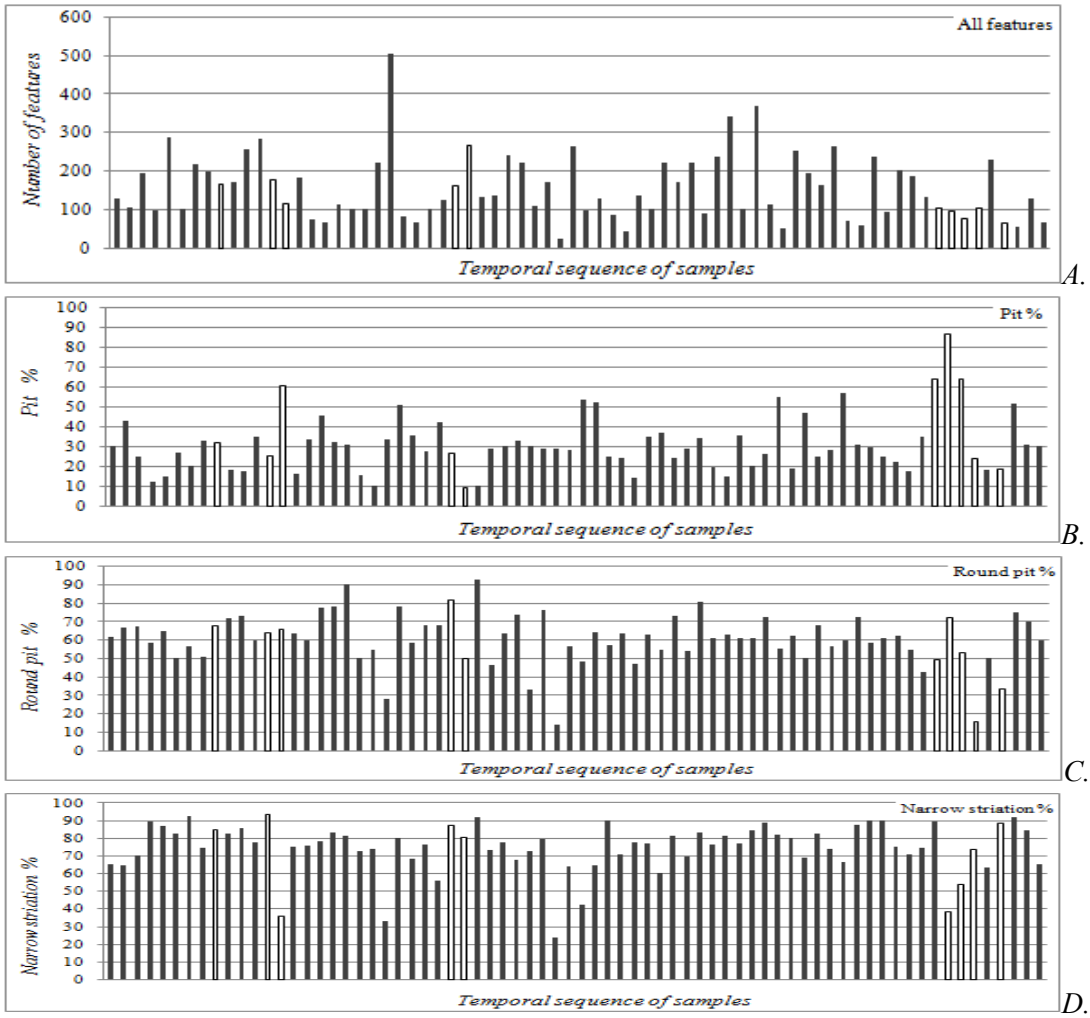


Figure 11.12

Chronological overview of dental microwear in Çatalhöyük specimens, earlier on the left, later on the right.(A) number of all features, (B) percentage of pits, (C) percentage of pits that are small and round, (D) percentage of striations that are narrow

(The markers for secure specimens are filled in grey, and the less secure specimens are unfilled)

As with the oxygen isotope evidence, the dental microwear data show no emerging chronological pattern, save one of variety within the parameters outlined in the general assessment of the data. In general terms this stands testimony to the unvarying dietary

resources available to Çatalhöyük's pre-slaughter herds throughout the 1200-year Neolithic settlement. Further investigation, by chronological and spatial groups, tests this assertion. The group of insecure specimens to the right of the chart, has been assigned to the latest levels of Neolithic occupation in the TP Area, but might be re-deposited from earlier primary deposition contexts. The dental microwear in three of this group is remarkable for having low total-feature numbers but high percentages of round pits. Discussion, on these and other outliers, is deferred to *Chapter 12*, as two of these three late-sequence specimens also have outlying oxygen isotope evidence.

11.4.5. Chronological assessment by analytical group

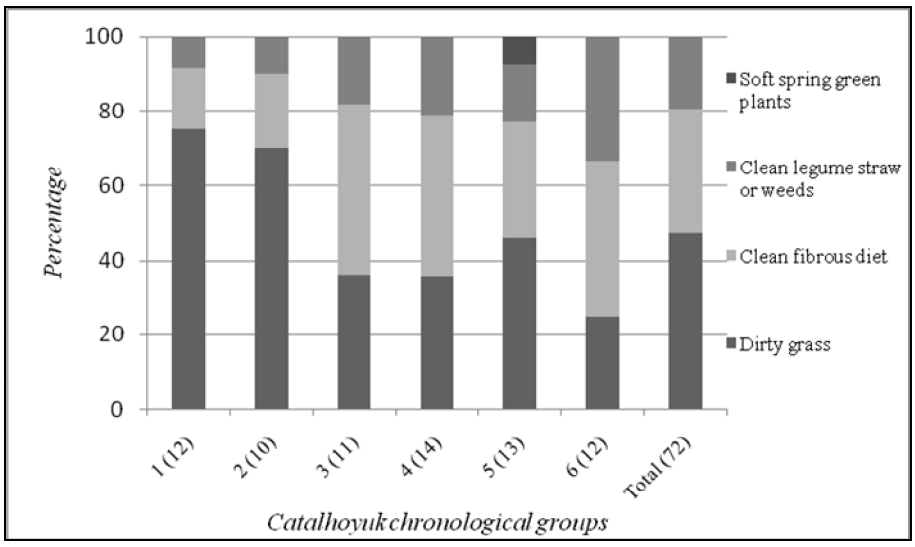


Figure 11.13
Chronological composition of dietary regimes, based on divisions illustrated in Fig 11.8

The information presented in *Figure 11.8* is re-presented as a bar graph (*Figure 11.13*) showing the chronological distribution of dietary regimes for each sheep, by percentage. The sample size of each group approaches that suggested suitable for secure analysis by Mainland (*Table 9*) and interpretation may be considered relatively robust.

The clearest differences emerge between groups 2 and 3. In groups 1 and 2 dirty grass-rich diets were most common,with less dry grass-rich food and very little soft, dry food. In

subsequent phases the diets were mainly cleaner grassy or soft foods with less dirty grass input. This tendency towards cleaner, dry diets was at its maximum in group 6. Chronological box-plots are presented (*Figure 11.14, 11.15, 11.16* and *11.17*) and the summary statistics are tabled in *Appendix 25*. The analysis focuses on the secure datasets, where specimen numbers in each group range from six to thirteen. Where differences emerge graphically, the Mann-Whitney-U non-parametric test will be used to test their statistical significance. As box-plots display median values and outliers separately they are able to highlight differences that are not apparent in *Figure 11.13*.

11.4.5.2. Total number of features

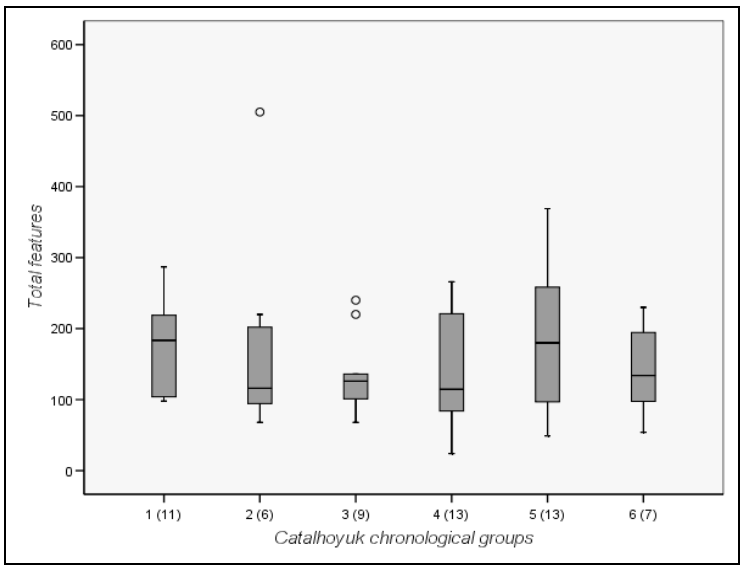


Figure 11.14
Box-plots of the distribution of total feature numbers in each chronological analytical group

The median number of features in each chronological group is very similar from group 2 to group 4 (*Figure 11.14*). Beforehand, in group 1, the total feature number is higher, but not significantly (Mann-Whitney, p = 0.21) (*Table 11.7*). Numbers are also higher later, in group 5, before dropping back to the lower level again in group 6; again this difference is not significant (Mann-Whitney, p = 0.518) (*Table 11.7*). As the archaeological specimens are contextually secure, Rivals and Deniaux (2005) argue that it is valid to continue to discuss data patterning even where statistical significance is absent.

Feature numbers are taken to be primarily a function of ingested soil in sheep diet before death, and thus the evidence points to most diets being dirtier in groups 1 and 5. In all groups, the lower end of the range is similar, indicating that the cleaner end of the dietary range was constant. The box-plots show one specimen in group 2 as an outlier; this suggests that the reliance on dirty grass-diets shown in *Figure 11.13* was, in fact, lower than in group 1. The upper limit is particularly low in group 3 suggesting sheep in this group had diets restricted to clean food, apart from the two outliers. Group 5, on the other hand, has a slightly higher upper value to its range; in this phase, sheep diets varied widely in cleanliness as well as being dirtier overall compared to previous phases. However as the box-plots do not discriminate between the types of dirty diet (soft or fibrous foods), *Figure 11.13* gives a more useful picture of feed distribution in group 5.

11.4.5.3. Pit-to-striation ratio

In all chronological groups, the median pit percentage is < 35% (*Figure 11.15*). The first group, group 1, has the lowest pit-to-striation ratio. The percentage of pits then rises rapidly, but not significantly (Mann-Whitney, $p = 0.51$) (*Table 11.6*), before gradually falling again a little until a slight rise in the last group, group 6. The range in pit percentage is lower in groups 3 and 4 than in the other groups.

The pit-to-striation ratio is an indicator of the contribution of monocotyledonous and dicotyledonous plants. The evidence shows that the dominant diet throughout the chronology was rich in monocotyledons – grasses, cereals, reeds and rushes. However, in the earliest phase more sheep ate these plants than in all subsequent phases. The '1-feature' evidence has shown that the diets in this early chronological group were relatively dirty. As the modern baseline links greater soil ingestion with wetter and muddier conditions, it can be argued that sheep in the earliest phase were more likely to have been eating winter graze before death.

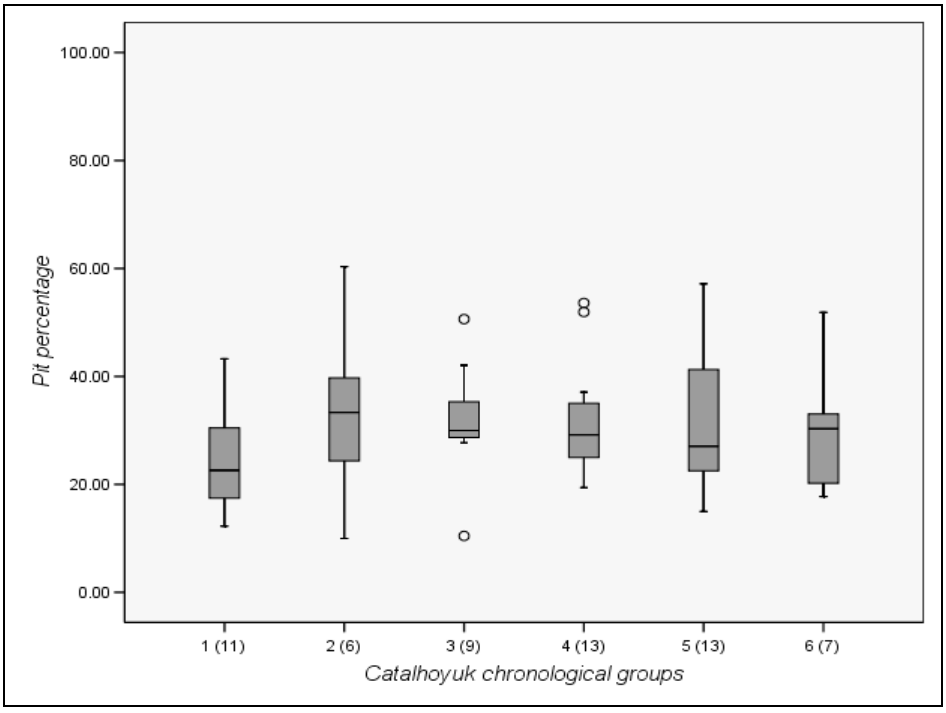


Figure 11.15
Box-plots of the distribution of the percentage of pits in each chronological analytical group

In the subsequent groups, the higher pit percentage and lower overall feature numbers indicate a slightly greater input of dry, soft food into pre-slaughter diets. In arid seasons sheep prefer to ruminate on dry grasses, rather than tall forbs that are often unpalatably spiny or aromatic later in their growth season (Hofmann 1998, 448; Papachristou 1997, 90); nevertheless the more palatable parts of dry forbs are eaten when pasture is particularly stressed.

The 13 individuals with clean soft-food diets, with no fibrous plant component, are evenly distributed throughout the chronological groups.

11.4.5.4. Width of striations

The chronological patterning of the percentage of narrow striations closely resembles the pattern of all features (*Figure 11.16*). This shows that diets causing narrow striations made the greatest contribution and were the greatest influence on variation. Striations, and in particular narrow striations, are associated with diets rich in temperate grasses and cereals. Differences in the range were most apparent in groups 2 and 4, and included diets causing

more broad striations. Possibly, C4 grasses, such as *Aeluropus* sp., played a larger part in sheep diet in these phases. Four individuals with high broad striation numbers emerge; they show no chronological patterning.

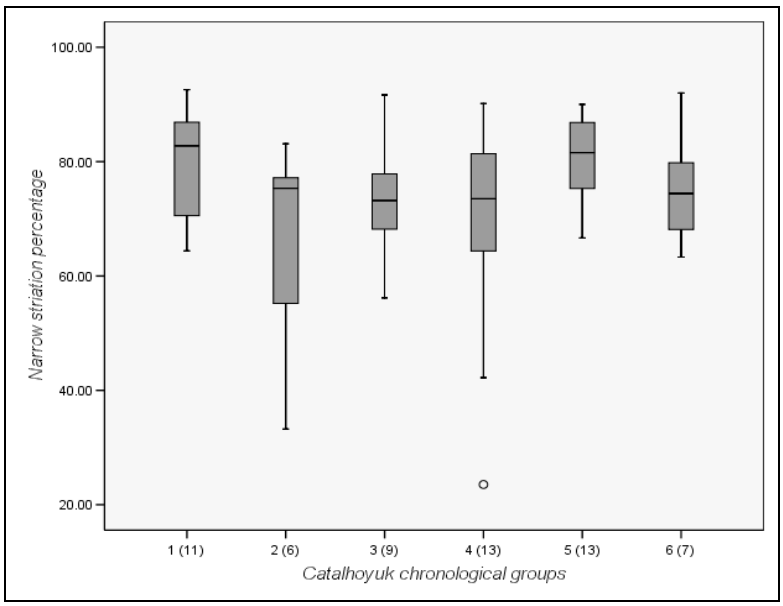


Figure 11.16
Box-plots of the distribution of narrow striations, compared to broad striations, in each chronological analytical group

11.4.5.5. Pit size and shape

Soft plants, associated with pit microwear, are a very small component of Çatalhöyük sheep feeding regimes. However, within this small input, the percentage of round pits, between 60% and 70% in all chronological phases, indicates that soft foods were plucked more often than tugged (*Figure 11.17*). Sheep are particularly adept at plucking low-growing, young grass shoots in preference to tugging on browse (Grant *et al.* 1998). In group 5, the narrow range stands out from other phases, suggesting a period where access to soft foods was more restricted to a particular type. Three outliers with higher, oval pit percentages represent individual sheep that died having eaten soft food such as leafy browse; they show no chronological patterning.

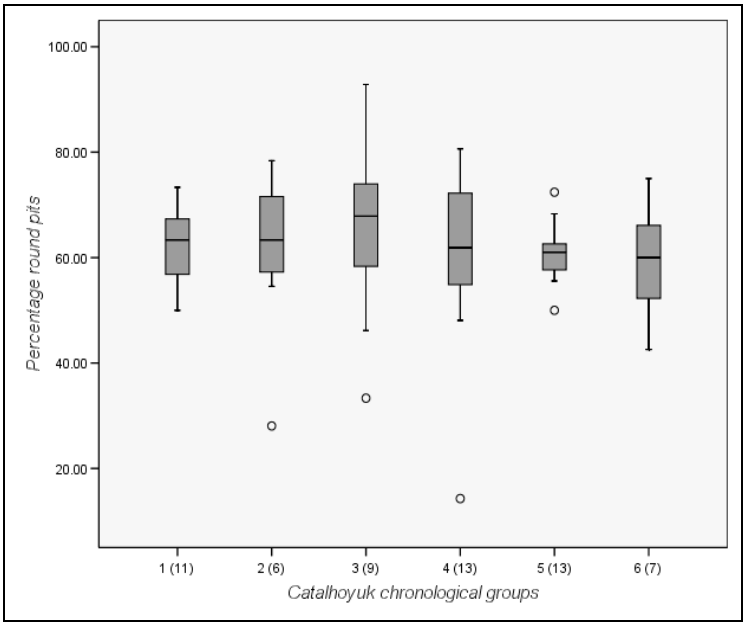


Figure 11.17
Box-plots of the distribution of small, round pits, compared to large, irregular pits, in each chronological analytical group

		Çatalhöyük groups	*N°.*	*Mean Rank*	*Sum of Ranks*	*Mann-Whitney U*	*Asymp. Sig. (2-tailed)*
Chronological Phases	Total features	1	12	13.08	157	41	0.21
		2	10	9.6	96		
	Total features	3	11	11.05	121.5	55.5	0.518
		5	12	12.88	154.5		
	Pit percentage	1	12	10.67	128	50	0.51
		2	10	12.5	125		
Spatial groups	Total features	South Area	43	40.73	1751.5	441.5	0.037
		Other Areas	29	30.22	876.5		

Table 11.7
Summary of Mann-Whitney -U non-parametric tests of statistical significance

11.4.5.6. Summary

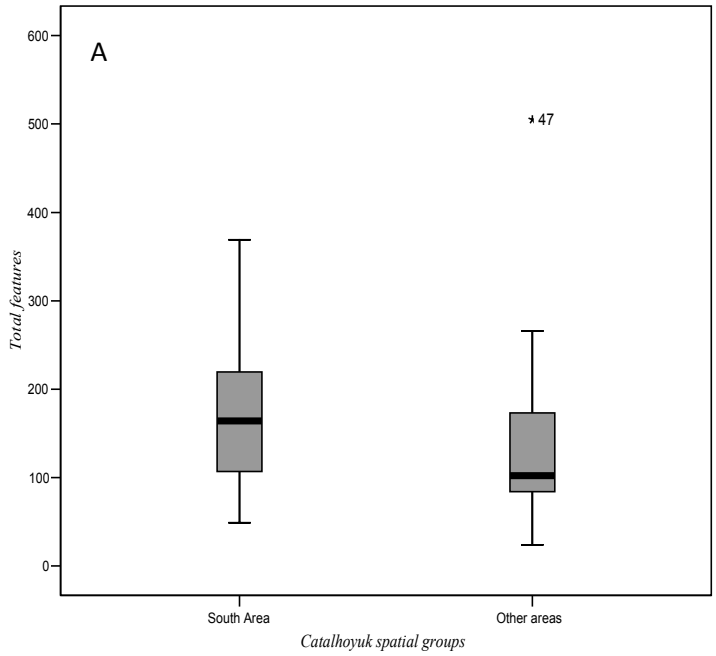
In summary, the evidence from six chronological phases of sheep dental microwear from Neolithic Çatalhöyük shows that, throughout the occupation, diets before death were dominated by grasses or cereals. In group 1, very few sheep died having eaten clean food, whether soft or fibrous, but by group 2, apart from two outliers, more of the fibrous diets were clean. In groups 3 and 4 there was also an increase in sheep eating clean soft diets. This pattern continues in group 6, although evidence of a variety of dirty diets in group 5 suggests a brief reversal in the trend.

11.4.6. Assessment by spatial group

11.4.6.1. Comparison by area

The dental microwear (*Figure 11.18*) in the South Area and in other Areas of Çatalhöyük has essentially the same components as discussed above; namely grassy diets that vary from clean to dirty and incorporate small amounts of plucked, clean, soft food. The spatial comparison reveals few differences, except in the total number of features category. The evidence from the South Area (44 specimens) shows that median sheep diets produced significantly more features than those from other areas (28 specimens) (Mann-Whitney, $p = 0.037$) (*Table 11.7*). It can be argued that South Area sheep were feeding on dirtier food than sheep in the other Areas.

The percentage of round pits seen in the South Area are tightly clustered, suggesting some focused feeding on certain plucked, soft, clean foods. In comparison, the other Areas show a wide range in the contribution of plucked, soft, clean food. This possibly indicates that sheep in other Areas had a more flexible access to soft foods, and consequently were not feeding so much on dirty food.



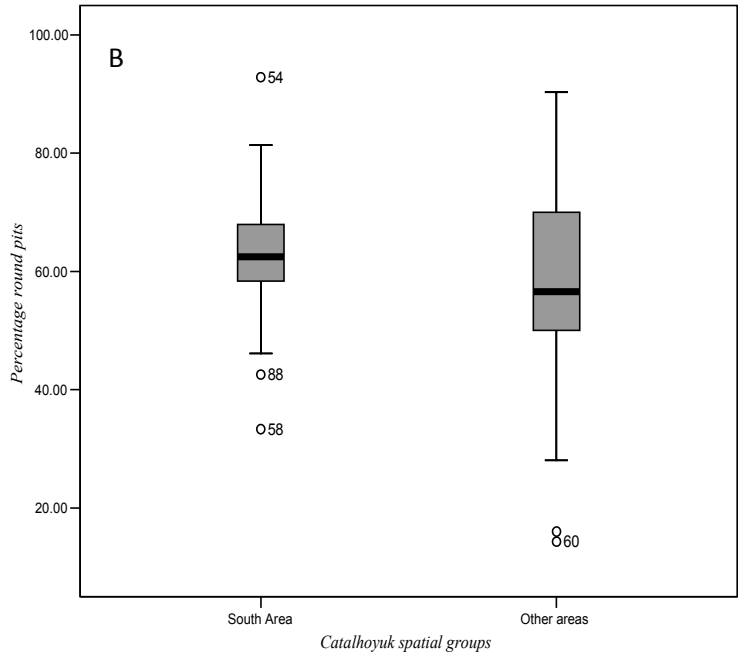


Figure 11.18

Box-plots of the distribution of (A) total feature numbers and (B) small, round pits, compared to large, irregular pits.

Specimens in the South Area (44), on the left, are compared to specimens (28) from all other areas of excavation, on the right

11.4.6.2. Comparison by building type

The second spatial comparison investigates patterns in the sheep from neighbourhoods associated with a long-lived house sequence (20 specimens) and from other house middens (17 specimens) (*Figure 11.19*). However, the evidence in all categories reveals no discernible differences in diets. There is, however, a difference in the range in all dental microwear categories. The long- lived-house neighbourhood evidence is more clustered, possibly indicating that the sheep had more focused dietary access before death.

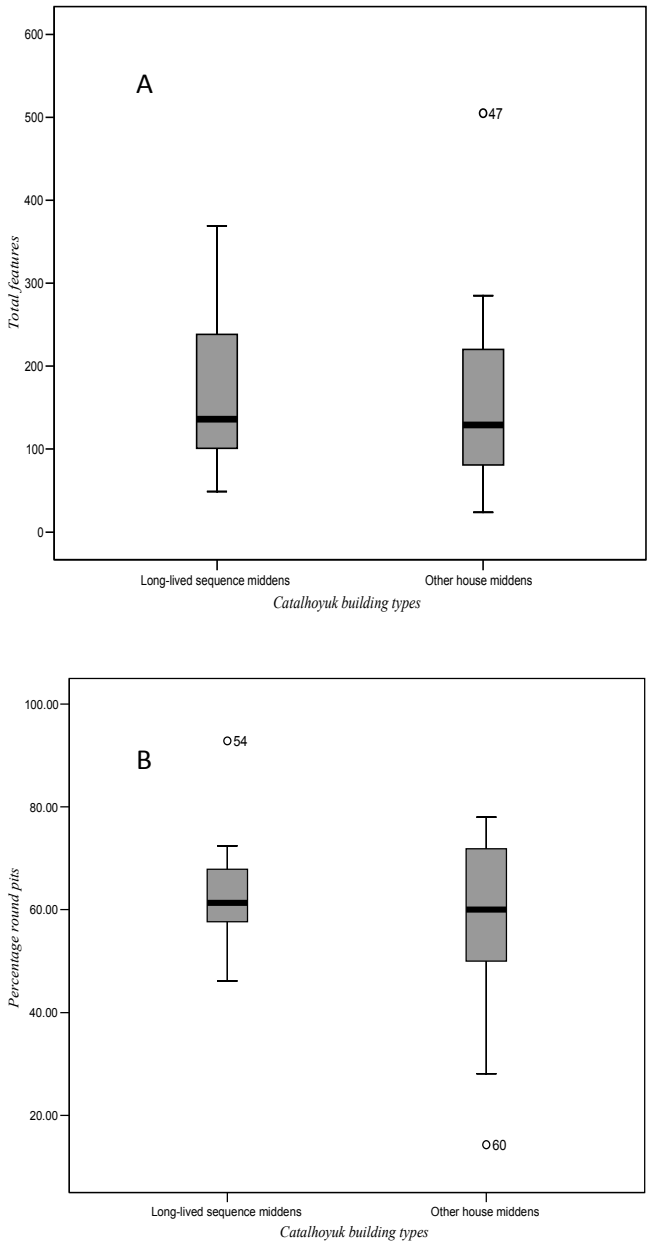


Figure 11.19

Box-plots of the distribution of (A) total feature numbers and (B) small, round pits, compared to large, irregular pits.

Specimens (20) from a neighbourhood with a long-lived sequence of buildings (on the left) are compared to specimens (17) from other house-neighbourhoods (on the right)

11.5. Conclusion

The plant-component analysis of food types available to traditionally reared Anatolian sheep showed early spring pasture of soft grass shoots and forbs to have the highest soil inclusions but the lowest phytolith content. Mature grasses, hay fodder, cereal stubble and arable by-product fodder had less soil and more phytoliths. On comparison with dental microwear in sheep eating those plant types, it is possible to establish that the number of total features, both pits and striations, can be associated more strongly with soil content. Soil ingested in wet conditions causes more dental microwear features than in dry conditions. The sample sizes in all modern material were very small, but the results both within and across different categories were consistent.

Within this model, Anatolian sheep were compared to published ungulates datasets. The results were again consistent, and confirmed that the Anatolian sheep could usefully add to the model constructed to analyse the archaeological dataset. However, the comparison highlighted over-counting on the part of the recorder.

The archaeological data were compared to all modern data. The results show that Neolithic Çatalhöyük sheep were predominantly grazing on grass-rich material that ranged from clean to dirty. As green pastures are browsed, not grazed, the dirty graze can be associated with winter pasture. There was a minor component of clean, soft material browsed. As green pastures are associated with high soil ingestion it is more likely that this clean browse represents fodder, possibly from weeds or legume by-products collected in the dry season.

The sample size of secure specimens allows six chronological groups to be analysed. In addition, evidence associated with two spatial areas and neighbourhoods of two types of building is investigated. The results show considerable consistency in the sheep diets before death. No significant patterns emerged, although there is some graphical indication of greater uniformity during the central three phases of occupation. There is a similar difference

between the specimens from the neighbourhood of the long-lived building sequence and those from other houses. There was a significant difference in the dirtiness of graze between different areas of occupation at Çatalhöyük.

CHAPTER 12. INTERPRETATION AND DISCUSSION

12.1. Introduction

In the *Introduction,* an overview of the different data sources used in this research to approach herding practices associated with one settlement (Çatalhöyük), within its regional (southwest Asia) and chronological (later Neolithic) context is provided in *Figures 0.1* & *0.2*. The data from these sources have now all been gathered and presented, some through literature review (*Chapters 2* to *6*) and some through original data collection and analysis (*Chapters 7* to *11*).

Through literature review, sheep behaviour (*Chapter 6*) was used to constrain the palaeoenvironmental evidence (*Chapter 5*) in order to construct a spatial and temporal outline of possible resources suitable for all parts of domestic herds in the Çatalhöyük landscape. The original research in this thesis aims to place sheep within this landscape at certain points in their lives by modelling high resolution oxygen isotope and dental microwear data from the teeth of individual archaeological sheep (*Figure 7.15* and *Table 8.2)* Additional evidence derived from modern comparative data collected in this project refined both dataset models (*Tables 10.7*, *10.9* and *11.4*).

In this chapter, discussion and interpretation is conducted through a series of questions implicit in the main research interests of this research. As the chapter progresses, the questions move from herding practices to more inferential ones of general economic interest, and then onto social organisation at both a settlement and regional level.

The first focus is on Çatalhöyük sheep, where empirical evidence (oxygen isotope results and dental microwear analysis) provides details of their dietary regimes and herd movement in the light of breeding behaviour (*Chapter 6*), and also of product goals established by zooarchaeological analysis (*Chapter 4*). Each body of evidence is used to support or constrain evidence from other datasets in order to build an integrated interpretation. As domesticates, the lives of sheep reflect the work and objectives of their herders, and it is thus possible, in the second phase of discussion, to focus on the people of Çatalhöyük, their working lives, their economic and social relationships, and their place in the wider Neolithic community, drawing on evidence of the material culture of Çatalhöyük (*Chapters 3*) and herding practices in central Anatolia and southwest Asia (*Chapter 2*).

12.2. What could the palaeoenvironment offer to herding?

12.2.1. Introduction

Before their territory was restricted, Bozdağ wild sheep roamed seasonally from summer in the hills to winter on the plains, following new grass growth and the most benign weather conditions (*Table 6.4*). The most nutritious and palatable plants are prevalent throughout spring and autumn (*Figure 12.1*). In summer, wild sheep eat dry grasses and legume weeds. Domestic sheep eat similar diets by preference and, when confined to fodder or restricted grazing areas, hay and legume straw are more nutritious than cereal straw or mature herbaceous plants; leafy tree browse is the least palatable food (Andrzejewska & Gyllenberg 1980; Hofmann 1989; Landau *et al.* 2000; Little & Leslie 1999). It might be expected that the feeding behaviour of Neolithic sheep was similar to wild sheep, and that the new niches of their domestication were still relatively unchanged or unspecialised.

12.2.2. Spatial resource use

At first glance, the overwhelming evidence of grass-rich diets (79.2%), inferred in *Chapter 11*, might support a model of vertical transhumance for Çatalhöyük herding, emulating wild

	Soft Diets		*Fibrous diet*	
Graze	*Summer weeds*	*Spring pasture, field edge or fallow weeds, tillered crops*	*Summer grass, cereal stubble*	*Late autumn/ winter grass*
Fodder	*Weeds or legume straw*		*Hay or cereal straw*	
Archaeological sheep				
N°	13	1	23	34
%	19.4%	1.3%	31.2%	48%
N°	15		57	
%	20.7%		79.2%	
Sub-total %	93%	7%	40%	60%

Table 12.1
*Summary of dental microwear results (*Chapter 11*) showing the percentage of interpreted diets eaten by Çatalhöyük sheep before death*

sheep behaviour (*Table 12.1*). However, the evidence only comes from sheep before death, probably selected for slaughter and, furthermore, microwear signatures do not readily distinguish between grass diets; 40% might be associated with cultivated cereal by-products.

The oxygen isotope evidence might contribute to an interpretation of spatial resource use. As the evidence relates to the first year of life, the first few months give evidence of lambs as members of breeding herds. However ethnographic information shows that lambs can join other herd parts within weeks of birth, and are able to eat adult food by the end of their second month (Beck 1991). It is likely that, whilst growing to maximum meat-bearing size, lambs would have been treated as members of fallow herds for ten months of their first year, able to grow on less optimal diets and needing less close supervision from herders. It follows that the greater part of the oxygen isotope evidence relates to fallow herds and their spatial resource use.

With this proviso, the oxygen isotope evidence (*Table 12.2*), from *Chapter 10*, suggests that upland herding was not commonly practiced at Çatalhöyük, and that 83.7% of sheep were fallowed at lower altitudes on the marl plain, the alluvial fan, the sand ridges and the limestone terrace (hereafter collectively termed 'lowland areas'); in all these places perennial and annual grasses would have grown (*Figure 12.1*). Cereal crops would have grown in well-drained, fertile areas on the fan and terraces, and wetland reeds in marshy areas of the fan and plain. Soft non-fibrous plants might have been found in grassland, cultivated or ruderal habitats.

	Plain, fan, sand-ridges, terrace	*Shaded valleys in terraces and lower hills*	*Movement to higher hills or karstic spring*
Early spring	88%	0	12%
April	91%	0	9%
Late spring	86%	7%	7%
Average	**83.7%**	**7%**	**9.3%**

Table 12.2
*Summary of oxygen isotope results (*Chapter 10*) showing the interpreted season of birth and first year herd-movement percentages in Çatalhöyük sheep*

The remaining 16% of sheep (*Table 12.2*), the oxygen isotope evidence suggests, were fallowed in other locations during their first year (*Table 10.9)*. Reduced summer oxygen isotope values in a small number of sheep (*c.* 7%) might be consistent with these sheep having been both born and later fallowed year-round in shaded, well-watered habitats where there would have been an extended grass-growing season. Perennial river valleys cutting through the terraces and lower hillslopes could have provided such settings. Of the *c.* 9% irregular, non-seasonal oxygen isotope curves, one of the alternative interpretations is that these sheep were ingesting water in plants growing near karstic springs on the plain, which had an input of seasonally, and thus isotopically, averaged aquifer water. The other explanation is that these sheep could have been moved vertically up to higher hillslopes during summer, taking advantage of cooler weather and associated fresh grass growth.

12.2.3. Seasonal resource use

Food sources for Çatalhöyük herds would have been seasonally constrained, although possibly not to the same extent as in modern times (*Figure 12.1*). In winter, a cessation of grass growth would have been less frequent, if models showing 25% greater annual precipitation and Neolithic temperatures not falling below 5° are correct (COHMAP Members 1988; Roberts 1991; Rossignol-Strick 1999). In summer, grass senescence would have been exacerbated by the modelled rise in annual temperature of 2.5° C, but evapo-transpiration effects would have been ameliorated by the increase in annual precipitation.

Oxygen isotopes cannot reliably be used to investigate equinoxal seasons, and the near absence of dental microwear indicators of green pasture diets (*Table 12.1*) also precludes comment on springtime resources.

Minimum oxygen isotope values are remarkably consistent for both modern and archaeological sheep (*Chapter 10.2.2.1*) but, as modern sheep in each village experienced very different winter temperatures, it cannot be argued that winters were identical in the Neolithic and the present. The minimum results are difficult to interpret, and cannot be used to elucidate whether plant growth might have continued throughout winter. The dental microwear evidence, however, is interpreted as 48% of sheep dying after grazing dirty winter pasture (*Table 12.1*). If so, the use of this resource by sheep in herds awaiting slaughter suggests that winter grass growth was ample, even if muddy, at Çatalhöyük.

In summer, wild sheep reduce food intake and lose condition when mature grasses become depleted leaving only noxious mature weeds (Silanikove 2000). Loss of condition might not have been desired in domestic herds if it did not coincide with the exploitation schedule; herders might have had to seek out areas of extended grass growth in order to maintain condition in their sheep. The low summer values in the oxygen isotope evidence for 16% of

the sheep (*Table 12.2*) might indicate that some herders took this option, either in shaded valleys or on cooler hillslopes. The dental microwear evidence suggests that 31.2% of sheep might have been eating mature summer grasses before death and 19.4% might have eaten unpalatable mature weeds (*Table 12.1*).

The growing season would have continued longer near perennial water bodies or marshland. On the plain and on the fan, such water bodies would have been highly evaporative and saline, conducive to the growth of halophytic grasses and weeds. One interpretation of the oxygen isotope evidence for 9% of the sheep is that they were raised near karstic springs on the plains; if correct, this location would also be consistent with grazing on halophytic vegetation in summer. However, all the dry diets could equally have been stored fodder; all that may be determined is that herders were seasonally exploiting these food sources, whether for fodder or for graze.

12.2.4. Competition for grazing land

12.2.4.1. Alluvial fan

Competition for optimal grazing land would have been at its greatest on the alluvial fan for a number of reasons (*Figure 12.1*). Firstly, if the fan was largely reserved for cultivation, grazing areas might have been restricted, and possibly discouraged to prevent crop-trampling. Weeds growing on field edges or fallow fields have a short growing season and are not nutritious, but in springtime, tillering cereal crop shoots might have been encouraged.

Secondly, seasonally flooded or marshland areas are unsuitable for growing cereals or raising sheep, limiting cultivation to dryer areas and further reducing grazing for sheep herds. Dryer areas would have included the margins of wetland areas, where sheep might have grazed on nutritious wild grasses or young reed shoots in springtime. Thirdly, the fan

might have been reserved as a hunting territory, particularly if marshland and wetland was extensive; if so, neither crop cultivation nor sheep herding would have been practiced there.

The dental microwear evidence shows ample evidence of diets of muddy mature grasses, such as might have grown in autumn or winter wetland-edge habitats, and also of diets of clean weeds, but does not reveal any use of early spring and summer grasses, reed tips or cereal shoots.

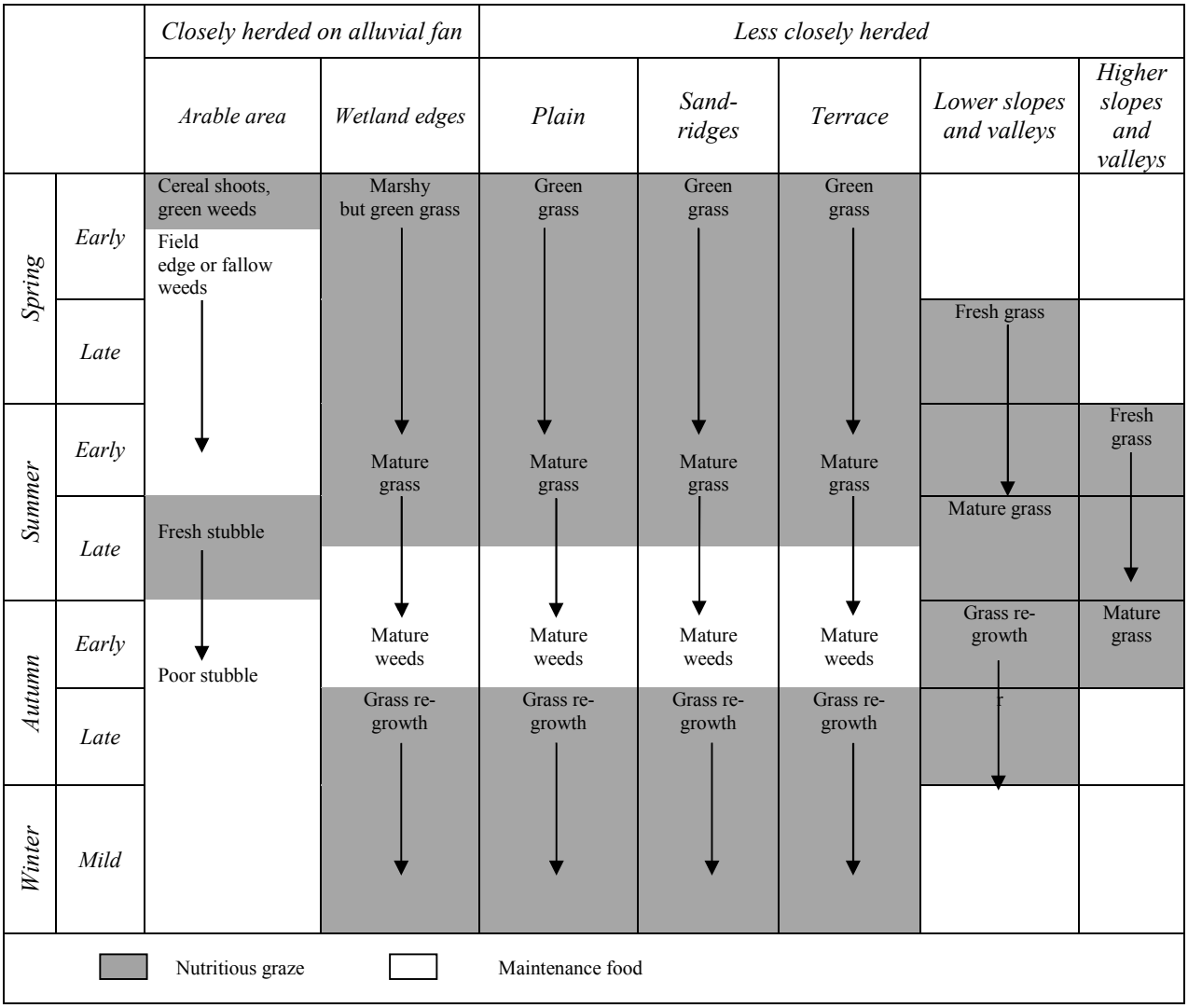


Figure 12.1
Chart modelling seasonal resource distribution in the Çatalhöyük landscape during the Neolithic

12.2.4.2. Terrace

There would have been less land competition on the more extensive, well-drained terrace, even if agriculture was practiced there. There might have been competition between hunting and herding in both grassland and woodland areas; grass-firing in autumn flushes out hunted animals but also removes perennial graze and kills annual grasses; unchecked woodland provides cover for hunted wild animals but its encroachment competes with grassland (McCorriston 1992). The microwear evidence (*Table 12.1*) of grass-rich diets (79.2%) might indicate grazing on the terraces, the dirty grass-rich diets (40%) might indicate that terrace grasslands were not fired by hunters in autumn.

12.2.5. Resources from cultivation areas

Cultivated areas potentially provide crop by-products as food resources for sheep. Stubble is commonly used by present-day herders, both settled and nomadic, to supplement seasonally depleted pastures in mid-summer; chaff and less-fibrous straw parts are stored by settled herders as maintenance fodder for winter use; farmers encourage light grazing in early spring to promote tillering in cereals. The dental microwear evidence (*Table 12.1*) shows that clean soft foods such as legume or weed fodder were fed to 20.7% of Çatalhöyük sheep before death, but the ample evidence of clean fibrous grass diets (31.2%) might indicate grazing on cereal stubble or foddering on chaff-rich by-products; alternatively it might indicate diets of dry-grass graze or hay fodder.

12.2.6. Summary

The oxygen isotope evidence relates to lambs in breeding and to growing juveniles in fallow herds whereas the dental microwear evidence relates to sheep destined for slaughter; as such only parts of palaeoenvironmental resource use can be discovered. In addition there are equifinalities in the dental microwear evidence that do not easily allow summer grazing to

be distinguishable from year-round fodder provision. Furthermore, palaeoenvironmental reconstruction and the location of crop cultivation still debated (*Chapter 5*).

On the first two points, discussion follows on the requirements of sheep when breeding or being fattened for slaughter, which might help constrain equifinalities and elucidate probable resource use. On the third point, the discussion continues on the assumption that there was crop cultivation on the alluvial fan. It is here, near the settlement, that certain herd parts could most conveniently have been raised on the more limited grazing areas and, therefore, where resource scheduling and herd movement to other areas might have been necessary.

12.3. What was the sheep breeding cycle?

12.3.1. Breeding ethology of wild sheep

Breeding behaviour in sheep was discussed in *Chapter 6*. It was argued that the quality of the seasonal food resource is the main influence in producing peak fertility periods. For ewes, food quality is also important during the last two months of foetal development, and for lactation levels in the first months of the lamb's life (Lancaster & Lancaster 1991). Soon after birth, lambs start eating suitable foods, increasing the quantity until they are fully weaned; during the first two months, in particular, benign weather conditions and optimum foods are essential if both ewes and lambs are to thrive.

Bozdağ wild sheep gain condition on autumn grass growth in preparation for rutting, fertile oestrus, and mating in December; gestation over *c.* 150 days leads to parturition in May; and in March and April, early spring grass growth provides the high quality nutrition needed to bring ewes into condition and for foetal growth. In summer, the temperature is warm enough for lambs and, with their movement uphill, fresh green grass pastures provide nutritional, digestible food. The decline in food resources in late summer dries off the ewes; by this time lambs can digest tougher, more fibrous mature grasses.

12.3.2. Breeding cycle of domestic sheep

The domestication of sheep provided the opportunity to adjust the annual breeding cycle. Thus, in modern Anatolian sheep mating takes place in October and lambs are born in March. The consequence of this breeding manipulation is that supplementary foods have to be given in late winter before birth when grass has not yet put on growth, and in late summer before mating when autumn grasses have not started new growth; ewes are moved onto poor pasture to encourage the cessation of lactation before the next breeding cycle (Ryder 1983). The advantage of an early birth season is that breeding herds can be moved away from cultivation areas before causing crop-trampling damage.

12.3.3. Breeding cycle of Çatalhöyük sheep

The oxygen isotope curves suggest that 60% of Çatalhöyük lambs were born in late spring (*Table 10.8*). If correct, these births resemble those in Bozdağ wild sheep and suggest that Çatalhöyük herders were not fully manipulating the birth season. Possibly, the mechanisms of breeding manipulation were unknown, considered unnecessary or unacceptable, or the added labour costs of providing food supplements were unfeasible.

However, the oxygen isotope evidence suggests the other 40% were born earlier in April or March; this pattern is closer to Anatolian sheep today. It is possible that there was a wider mating and lambing season in the Neolithic as grass growth continued for a modelled seven months throughout the warmer and moister winters (le Houérou 1977). Indeed, during the Neolithic, wild sheep, too, might have had a wider birth season.

12.3.4. Resource provision during the breeding cycle

The provision of optimal resources for large domestic herds at key points in the breeding cycle would have put pressure on resources, even for the later birthing group. If the birth season was controlled or even altered by the herders, pressures would have been greater on

the more limited seasonal resources for the earlier birth group. One solution to resource pressures would be new cereal stubble or fodder provision of nutritious hay, stored legume weeds or straw or cereal chaff and grain. Dental microwear analysis can offer no insights here as all the sampled sheep died long after they were yearling lambs.

A second solution to resource pressures would be to emulate wild sheep behaviour and move breeding herds to optimum conditions in shaded or uphill pastures at certain key times. However, the oxygen isotope evidence suggests such uphill movement rarely happened. On the contrary, microstratigraphical evidence of penning areas strongly suggests that some ewes and their lambs were confined to settlement edges (Mathews *et al.* 1997). Whatever the season, confined animals would have needed good quality fodder to survive.

12.4. What was the annual movement schedule of herds?

12.4.1. Herd splitting and movement in wild sheep

Wild sheep split into different herds and move into separate areas at different times of the year; this is linked to the breeding cycle and to the seasonality of food resources (*Table 6.4*). One herd consists of all the females and the male lambs; the other herd consists of all adult males. The two herds remain separate for most of the year, but come together during the rutting and mating season. At this point lambs are weaned, and the male lambs, which are now becoming reproductively active, join the male herds for renewed separation after mating.

Herd splitting serves three main purposes. Firstly, removal of the males reduces aggression; secondly, reducing the size of each herd lightens the impact of grazing, now spread over the landscape; thirdly the better resourced and protected areas can be targeted for breeding herds at key times.

12.4.2. Herd splitting in domestic sheep

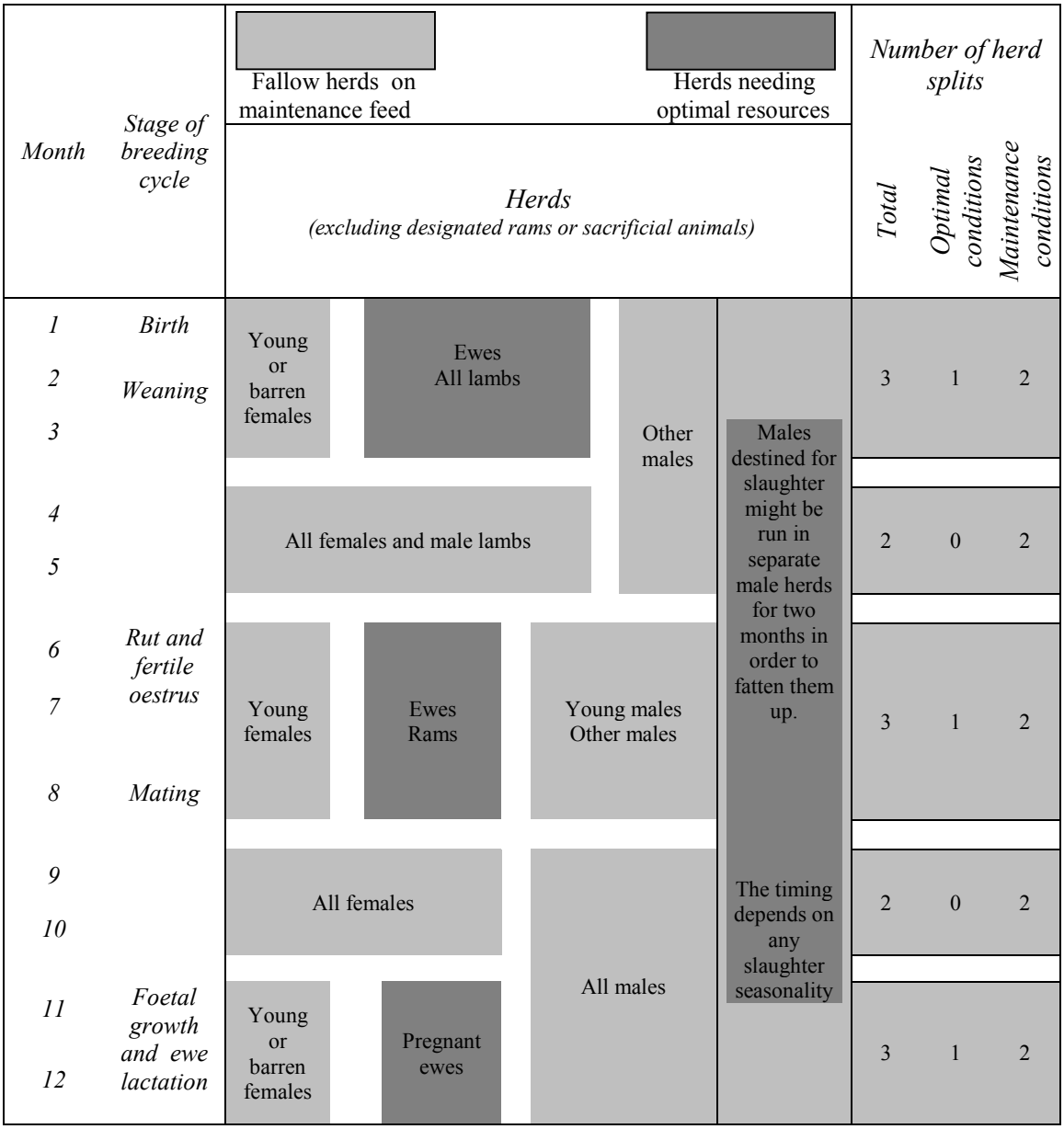


Figure 12.2
Chart modelling the herd splitting schedule for a domestic sheep herd with one birth season

Splitting of domestic sheep herds, as seen so wildly in the ethnography of herding (Chapter 6), builds on wild sheep ethology, but is complicated by labour scheduling and product goals. Herd parts that require optimal food and conditions, and the most intensive herding, might now include young males being brought on for slaughter, and ewes kept in milk for human consumption. Pressure on resources consigns non-breeding females, whether too

young or barren, to fallow herds, which are run separately from fallow males (unless castrated) in order to control aggression and mating. It is possible to return ewes in the early stages of gestation, or older lambs in the last months of weaning, to fallow herding on less optimal resources. Apart from designated rams, male herds raised for their meat might be split about two months before slaughter into those to remain fallow, and those to be fattened up for slaughter.

At any one time, in a herd with one breeding season, the number of herd parts will be at least two and often three (*Figure 12.2*). When three herds are being run, one will require optimal food and the other two can be maintained on less nutritious material such as field edge or fallow weeds or older stubble and coarser parts of cereal straws; when there are two herds, both may be fallowed. Sheep designated for slaughter need fattening for two months and might be run as a separate herd at certain times. Should the birth season extend over a longer period, or be divided into a late and early season, the model becomes more complex.

12.4.3. Herd movement in domestic sheep

The spatial deployment of herds depends on seasonal resources, labour scheduling, and settlement product demands. Where milk is an important, if not optimum, product goal, milking ewes might be herded near the settlement for easy access. Whatever the product goals, mating adults might be better controlled, and birthing ewes and young lambs better protected near the settlement.

During spring and early summer, herding close to cultivated areas might lead to crop damage, and removal of herds might be the better option. Fallow herds might be droved to more distance areas to spread their impact on more extensive grazing grounds. Pre-slaughter herds, too, might more easily be fattened up away from the settlement, only being droved in for slaughter. At key points in the year different herd parts have to be moved to different

locations, splitting from or joining with other herd parts, as their feeding requirements or labour scheduling need adjustment.

12.4.4. Herd splitting and movement at Catalhoyuk

The oxygen isotope evidence (*Table 10.8*) does not immediately suggest that Çatalhöyük herds were further divided into discrete groups with different breeding seasonality, as is practiced in some present-day communities in order to conserve resources and insure against resource failure and herd collapse (Cranstone 1969; Ginstburger *et al.* 1990).

As the palaeoenvironmental evidence suggests that optimal pasture would have been at its most limited near the Çatalhöyük settlement (*Chapter 5*), as much herd movement as possible would have been advantageous. The oxygen isotope evidence (*Table 12.2*) points to any distant herding having been largely restricted to lowland areas, with very few sheep possibly herded elsewhere; Sheldon's (2009) osteological evidence adds support to this interpretation. Pasture near the settlement could have best been reserved for the seasonal pasturing of herd parts that required more attention and optimal feeding and, used less intensively throughout the year, pastures would have time to recover, forestalling parasite prevalence common to stressed pastures, sheep folds or pens.

The movement of fallow herds would have removed resource and land competition nearer the settlement whilst providing the most optimal grazing conditions away from diseases associated with waterlogged areas. Apart from the most stressed months of late summer and early autumn, young males being fattened for slaughter could have been herded on more open, distant grasslands as they would not have needed added attention and could have been herded more easily; in addition, extensive herding practices would have allowed sheep to take advantage of protection offered by gullies and rocky overhangs. Where sheep seek protection from heat, a reduced range of oxygen isotope values might be expected, as is seen in 7% of Çatalhöyük sheep (*Table 12.2*).

In many modern pastoralist systems, movement of herds away from villages is scheduled to coincide with the crop growing season as well as seasonal pasture availability; birthing is usually timed so that lambs are able to make the journey (Barth 1961). The breeding cycle with a May birth season, seen in wild sheep and in the greater part of Çatalhöyük herds, is suited to the seasonality of natural food sources, but if lambing herds were kept close to the settlement, they would coincide with any cultivation of crops; this might lead to conflict and land competition. Early births in March, as seen in modern Anatolian herds (*Tables 9.1 & 2)* and in some Çatalhöyük sheep (*Table 10.8*), would mean that lambs were old enough to move away from growing crops. However, later in the year, arable by-products might be necessary for bringing rutting and mating sheep into condition in the absence of autumn grasses; and also in late winter for the final stage of foetal growth in the absence of spring grass growth.

12.5. What were the arrangements for slaughter?

12.5.1. Introduction

Slaughter practices at Çatalhöyük have been investigated by zooarchaeological analysis (Russell & Martin 2005; Twiss *et al.* 2010) (*Chapter 4*). Body-part representation suggests slaughtering took place near the settlement, but mortality profiles do not offer the precision needed to approach slaughter seasonality. Zooarchaeological analysis shows that culling began when lambs were six months to one year old, peaked between one and two years old, but continued in smaller numbers until four years old (*Figure 4.4*). Sheep reach their maximum size and carry the most meat as they approach young adulthood at two years old; the zooarchaeological evidence points to meat consumption having been a major consideration in sheep herding practices (Arbuckle *et al.* 2009; Russell & Martin 2005; Twiss *et al.* 2010).

12.5.2. Age of slaughter

The evidence presented in this thesis adds little to previous zooarchaeological analysis of herd mortality profiles. The sampling strategy suitable for both datasets resulted in a marked bias towards older animals (*Figure 9.3*); only eight specimens were from sheep that died in the peak age period between one and two years old. However, when the cohort of sheep that were slaughtered by four years old is added, the number rises to 37. As fat was an important contributor to diet at Çatalhöyük, older animals with higher fat content might also have been valued and considered part of the slaughter stock, rather than as incidental take-off. With these provisos, the complete cohort of specimens analysed in this thesis will be discussed.

12.5.3. Slaughter seasonality

Dental microwear analysis contributes significantly to the question of Çatalhöyük slaughter seasonality. There are two stages to consider with slaughter herds, firstly the month or two needed to fatten up sheep on optimal diets, and secondly where and when slaughter took place. Dental microwear provides a record of the final weeks before death, and in its interpretation, it is necessary to extrapolate backwards to the period of fattening up.

Slaughter seasonality has practical considerations to take into account in addition to any arising from social or ritual demands. Firstly, if male lambs are to be culled, then it is timely to do so before they reach fertile maturity. Secondly, once juveniles reach their maximum meat weight there is little purpose in keeping them alive on valuable food resources any longer and, in particular, it is expedient to slaughter them before the high costs of stabling and foddering over winter. Ethnography shows that late autumn is the most usual time of year for slaughter, before winter but after autumn-fed grass re-growth has brought the sheep into prime condition (Dahl & Hjort 1976).

There are three times in the year when non-fodder optimal food resources would have been available for fattening herds and that have supporting dental microwear evidence (*Table 12.3*). Firstly, sheep slaughtered in early summer could have been fattened up away from the fan on late spring green pastures, but less likely on the fan as green pasture might have been reserved for early lambs born in March and for May births. Dental microwear pointing to clean grass diets (*Table 12.1*) is consistent with the increasing maturity of grasses at this time. Secondly, sheep slaughtered in late summer could have been fattened up away from the fan on early summer mature pastures but not on fresh stubble possibly reserved for May lambs; the dental microwear evidence of clean soft foods is consistent with the mature weeds available at slaughter time (*Table 12.1*). Thirdly, sheep slaughtered in winter could have been fattened up on autumn pasture re-growth; this more probably would have been away from the fan as bringing breeding herds into rut condition might have precedence on the fan pastures. The dental microwear indicating muddy winter pasture grasses is consistent with food availability at slaughter time (*Table 12.1*).

If this analysis is correct, and assuming for the moment that sheep were grazed, and not foddered, then 31.2% of Çatalhöyük sheep were slaughtered in early summer, 19.4% in late summer and 48% in winter. Early winter slaughter would have reduced herd resource needs as winter deepened, and late summer slaughter would have been timely in order to remove herd parts before the greatest optimal resource stress in early autumn. However, as has been reiterated, fodder could have been given at any time, either to fatten-up, or to maintain animals due for slaughter.

Possible fattening-up season		*Possible fattening-up diet*		*Diet at death 6-8 weeks later*		*Reasons against this season (unless foddered)*		
		Fan	*Else-where*	*Diet*	*DMA*	*Fan*	*Else-where*	*DMA*
Spring	*Early*	Green pasture	Green pasture	Green pasture	Dirty soft	March births	May birth foetal growth	Not present
	Late	Green pasture	Green pasture	Mature pasture	Clean fibrous	March early lambs May births		
Summer	*Early*	Mature pasture	Mature pasture	Fresh stubble, mature weeds	Clean soft	May lambs on fresh stubble		
	Late	Fresh stubble	Mature weeds	Old stubble or mature weeds	Clean fibrous or clean soft	Pre-rut conditioning for March births	No nutritious foods	
Autumn	*Early*	Old stubble	Mature weeds	Autumn pasture re-growth	Dirty fibrous	Not nutritious	Not nutritious	
	Late	Autumn pasture re-growth	Autumn pasture re-growth	Autumn pasture re-growth	Dirty fibrous	Pre-rut conditioning for May births		
Winter		Autumn pasture re-growth	Autumn pasture re-growth	Green pasture	Dirty soft			Not present

Table 12.3
Chart modelling possible slaughter seasons (highlighted grey) at Çatalhöyük, based on dental microwear evidence and food availability

12.5.4. Place of slaughter

Although the body part evidence points to sheep slaughter close to the settlement, the above analysis of resource availability suggests that the targeted herds were held on pasture slightly further away on the plains or sand-ridges whilst being fattened up. Ethnographic evidence shows that sheep do not lose condition if they are droved slowly, grazing on the hoof, no more than 16 to 30km per day (Lancaster & Lancaster 1991). The dental microwear evidence would retain this dietary signature up to two weeks later at death.

In addition to resource competition, herds being fattened up for winter slaughter might have experienced progressively unsuitable water-logged pastures as the rains set in. On the dryer plain and well-drained sand-ridges grazing might more easily have continued through late autumn, with herds being brought back for slaughter and herders returning to the settlement as winter began. For herds fattened for summer slaughter, good grass resources would be available through much of the wider Çatalhöyük landscape and it might have been unnecessary to compete for more limited fan resources.

12.5.5. Summary

It is now possible to add more detail to the model presented in *Figure 12.1,* building on the discussion above (*Figure 12.3*). The likely herding locations of three herd parts – early-season and late-season breeding herds, and pre-slaughter herds – are mapped onto the resource plan. The chart shows where breeding herds and slaughter herds might have been whilst they were receiving optimal food or care. As palaeoenvironmental modelling suggests that the Çatalhöyük fan was surrounded by extensive lowland grasslands, it is assumed that maintenance food for fallowed herds would not have been in short supply, and so this information has not been added.

It is possible that optimal fodder could have been given at any time. In early autumn, fodder might have been essential for both herds in different stages of rut. At times of the greatest resource competition between herds, it is likely that fodder would have been reserved for breeding herds rather than for those being fattened for slaughter. It would also have been necessary to reserve fodder in case of bad winters.

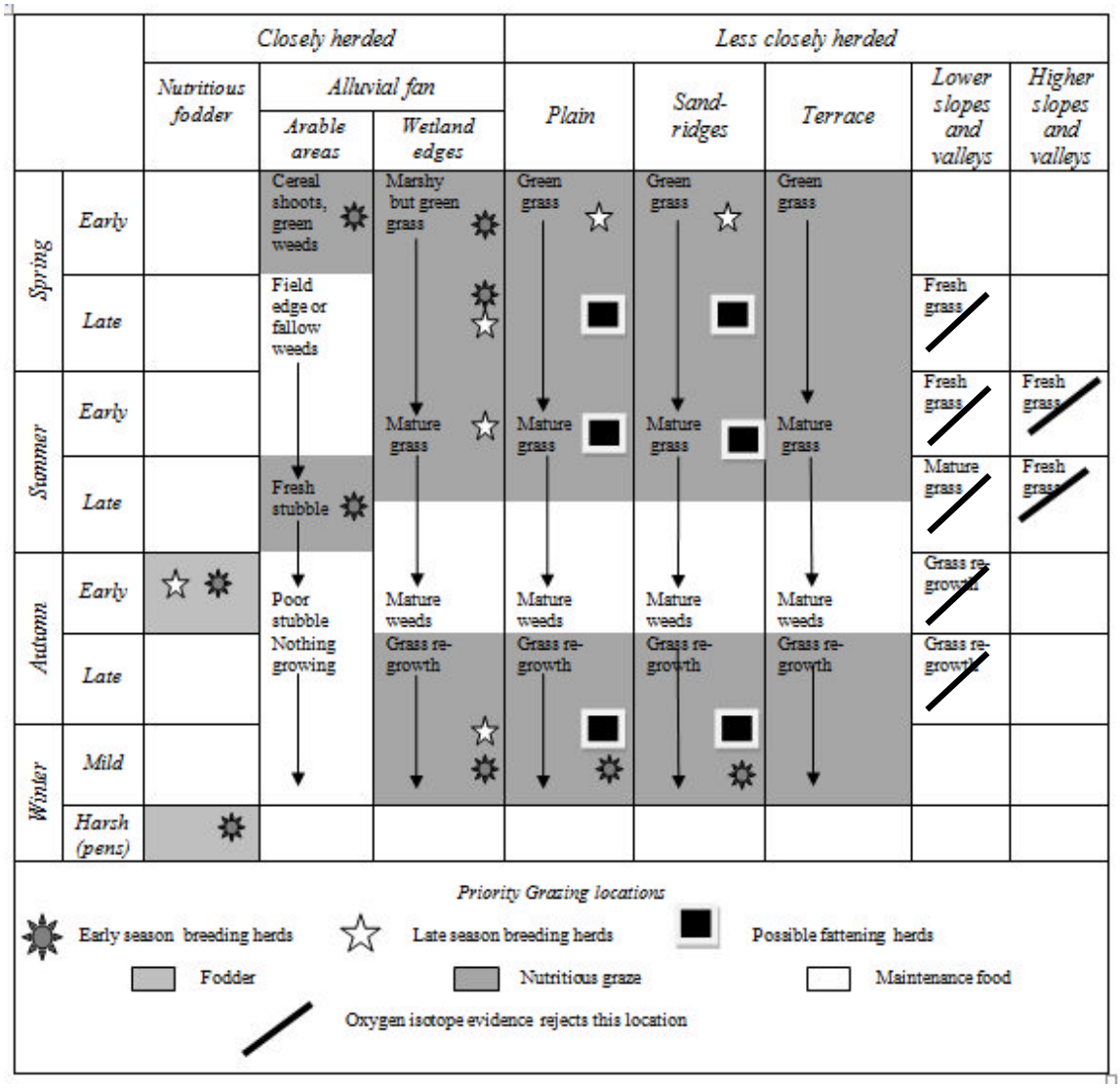


Figure 12.3
Chart modelling seasonal resource distribution in the Çatalhöyük landscape with interpreted herd pasturing locations added for early-season (sunbursts) and late-season (white stars) breeding herds and for herds being fattened for slaughter (black squares)

12.6. How were herds maintained over time?

12.6.1. Introduction

Up to this point in the discussion, interpretation has confined itself to an overall assessment of the feeding, breeding, movement, herd splitting and slaughtering patterns that might have pertained in Neolithic Çatalhöyük. It is possible to discuss how the viability of sheep herds was maintained so successfully throughout the Çatalhöyük Neolithic occupation, and

whether strategies changed over time in order to maintain that security, by examining the evidence in shorter analytical groups. Five groups used in this thesis encompass periods between 125 and 175 years, but the first group is possibly as long as 800 years (*Table 9.9*). The sample size of each group was large enough for analysis of the dental microwear results to be considered secure but, for the oxygen isotope results, the smaller sample sizes demand that interpretation is restricted to indicative patterning only. At this point, discussion utilises these analytical groups but, in summarising the interpretation, the new Hodder phasing and dating systems will be introduced.

12.6.2. Changing pressures on sheep herding

Steadily rising population levels at Çatalhöyük (Cessford 2005b) might be expected to have made extra demands on sheep products, although zooarchaeological analysis has not yet revealed evidence of product goal intensification (Russell & Martin 2005; Twiss *et al.* 2010); it is possible that changes in resource or labour allocation would have enabled more effective herd management and exploitation. The introduction of cattle management and domestication to the Çatalhöyük economy might have altered reliance on sheep products. Towards the end of the settlement, the climatic downturn heralding the 8.2k event might have had considerable effects on the management of sheep herds and their food resources.

Zooarchaeological analysis (*Figures 4.2 & 12.4*) identified three stages of domestic animal exploitation, where the earliest (group 1a in this thesis) and latest (groups 3, 4, 5 and 6 in this thesis) assemblages have over 80% sheep, and the middle (group 1b and 2 in this thesis) have 60–65% sheep. The middle stage is accompanied by a marked increase in cattle and deer, and suggests changing resource exploitation during that time. If both cattle and deer were being hunted it might indicate less reliance on sheep herding, that sheep herd security was at risk, or that social attitudes to domestication were less favourable. However, cull patterns and morphometric evidence point to early cattle management in the second stage followed by full domestication in the third. Changing cattle exploitation would have also

affected sheep herding practices; the zooarchaeological evidence might imply failing sheep herds, but could also suggest a changing economic balance. Either way, the allocation of food and labour resources to sheep would have changed to accommodate the herding and nutritional needs of cattle.

12.6.3. Solutions to changing pressures

Oxygen isotope and dental microwear evidence might contribute to interpretation of the maintenance of caprine herd security at Çatalhöyük in five respects: continued herd protection from climate extremes, improved breeding rates, introduction of new stock, more efficient scheduled access to optimal resources, and adjustments in sheep herding to accommodate the introduction of new cattle domesticates.

12.6.3.2. Protection from climate extremes

Wild sheep seek shelter from extreme conditions throughout the day and avoid seasonal extremes as they follow food resources; domestic sheep exhibit the same behaviour where they are able to do so. Herders might offer protection to their most vulnerable or most valued animals.

The oxygen isotope results are interpreted (*Chapter 10.2.2.2*) to suggest that winter conditions experienced by sheep remained remarkably similar throughout most of the occupation, until a decline is indicated in the last phase. Interpretation suggests that summer conditions also remained similar, but to a lesser extent, throughout most of the occupation, but became more extreme in groups 5 and 6. If the constancy seen throughout most of the occupation indicates herd protection that worked well, changes in the later groups might indicate worsened winter and summer conditions. The changes might be explained in a number of ways; the onset of the 8.2k global downturn, where herders did not, or could not, alter their arrangements for herd protection from seasonal extremes; social changes

heralding settlement abandonment, where herd protection priorities might have been lowered; or a combination of both.

The oxygen isotope evidence for herd movement strategies throughout the Neolithic occupation of Çatalhöyük (*Figure 10.21*) suggests that almost all herd movement took place within lowland areas, where herd security was only rarely promoted by movement to cooler, more grass-rich locations in the summer. Oxygen isotope evidence does not readily distinguish between different lowland locations, and so little more can be elucidated about herd movement as a means of maintaining herd security.

Turning to the few sheep that might have been herded elsewhere, each chronological group shows slightly different numbers, but if this was due to changes in herd movement practices it appears to have been non-directional. It is possible that the variation is a function of the small sample size.

12.6.3.3. Increase in yearning rate

A herding strategy that increases the number of lambs born each year is a valuable tool in managing risk through surplus production; raising the nutritional plane of sheep is the prime strategy (Dahl & Hjort 1976; Russell 1988). Improved nutrition is unlikely to be an automatic corollary of domestication; indeed body-size reduction associated with early domestication is considered to be due, in part, to restricted food resources and unhealthy, overcrowded conditions. It is more likely that herders would have had to adjust and target food resources to certain herd parts in order to improve yearning rates. In order to alter the birth season, seasonally manipulated feeding regimes would have had to have been accompanied by controlled mating strategies.

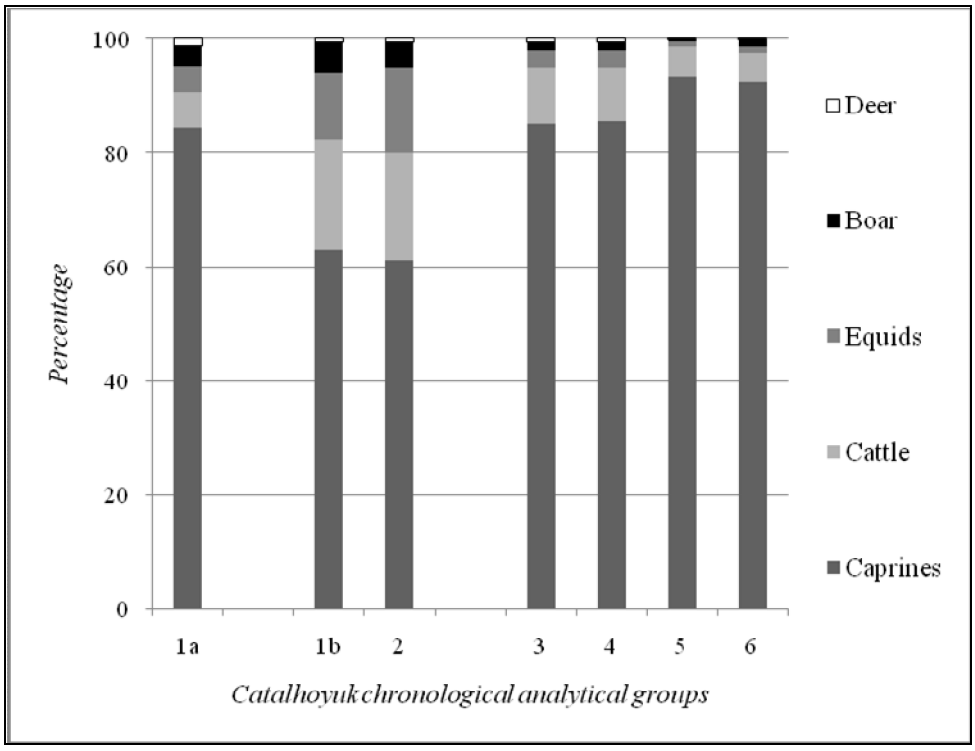
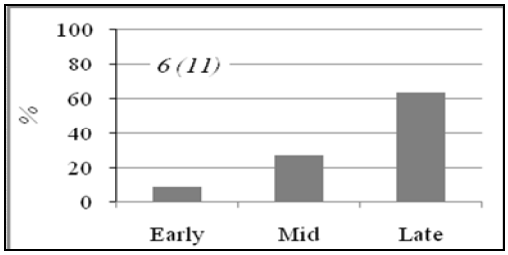
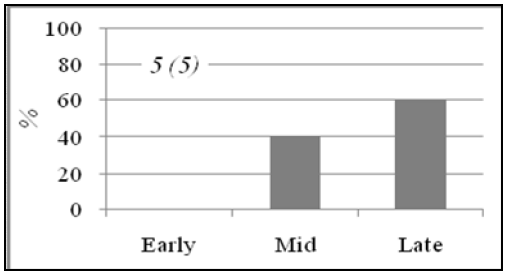
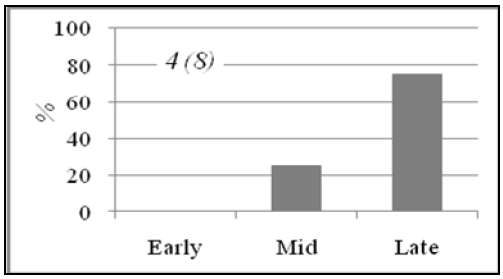


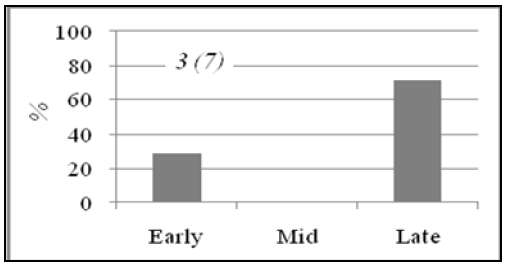
Figure 12.4
Chronology of NISP % of major meat animals at Çatalhöyük, by analytical grouping used in this research.
After Twiss et al. *2010*

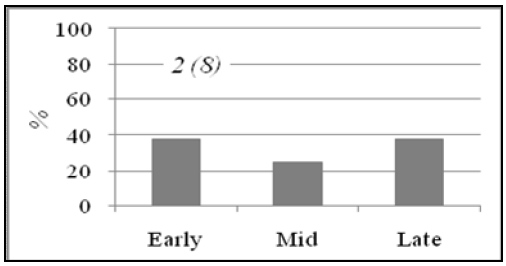
The decline in caprine reliance after group 1a (this thesis) might have been due to less robust herd security, although not falling below 60% at any time; in group 3 reliance rose again to around 90% (*Figure 12.4*). Evidence from the curves of sequential $\delta^{18}O$ values gives some indication that attempts were being made to control the lambing season around this time (*Figure 12.5*), although sample size is small. In group 2 there are increasing numbers of lambs born in early spring, and by group 3, the bimodal distribution might indicate that two herds were being run, one with early spring births and one with late spring births. From group 4 onwards late lambing appears to become the dominant herding practice. It might be argued that these changing herding strategies were introduced to re-dress failing herd security, although it is interesting that herders apparently returned, with increased commitment, to managing a late birth season for their herds.











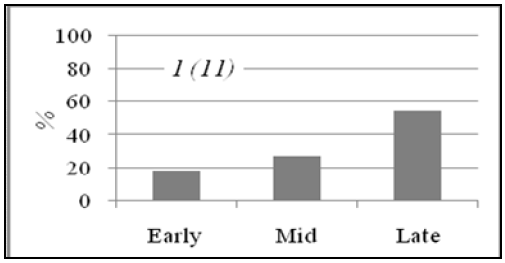


Figure 12.5

Charts showing the chronology of sheep birth season distribution at Çatalhöyük by analytical grouping

(earliest at the bottom, latest at the top)

The oxygen isotope evidence for birth seasonality in group 6 suggests that variation in breeding practices increased slightly, as they did for herd protection from climate extremes. If correct, it can be argued that this loss of consistent practice marked a declining ability to maintain herd security. Conversely, variability in practices might be evidence of deliberate diversification strategies to manage increasingly unreliable resources in order to maintain herd security.

12.6.3.4. Dividing breeding herds

Herd security might also be maintained by running separate herds on different annual schedules. This practice serves to spread labour demands, to lighten seasonal demands on food resources and pastures in particular, and to manage risks incurred from extreme seasonal effects such as flooding or drought. The limited evidence of bimodality of the birth season suggests that this strategy might have been initiated in group 2 sheep and practiced fully in group 3 (*Figure 12.5*). If so, it is to be noted that herders do not seem to have continued running two herds after group 3; possibly, this strategy was no longer considered necessary or other strategies for managing risk and maintaining herd security were preferred.

12.6.3.5. Access to optimum resources

Access to optimum resources has largely been discussed above, where *Figure 12.3* summarises the interpretation of the complex scheduling of different herd parts onto pastures (or to fodder) of different quality throughout the year at Çatalhöyük. This section considers whether this schedule had the flexibility needed to maintain herd security in the face of changing pressures. The interpretation of the oxygen isotope evidence suggests that long distance herd movement was not part of the repertoire, but that adjustments in the birth season might have played some role. The dental microwear analysis does not give direct evidence of dietary regimes in breeding ewes and young lambs, where herd security might have been the greatest concern, but it is argued that the feeding of sheep destined for

slaughter would have accommodated their needs so that any adjustments for slaughter herds would reflect, in part, changing herd security arrangements in breeding herds.

The first point to emphasise is that the dental microwear evidence (*Figure 11.13*) suggests no recourse to leafy browse, the least optimal, stress fall-back material, at any time during the Neolithic at Çatalhöyük, even for sheep about to be slaughtered. In fact the dental microwear evidence shows that resource provision for animals earmarked for slaughter throughout the whole of the Çatalhöyük Neolithic occupation was overwhelmingly rich in fibrous plants, with little recourse to soft foods.

Winter resources will be considered first. In group 1 in particular, but also in groups 2 to 5, sheep slaughtered in winter had access to winter graze suggesting that, in general, there were adequate resources to maintain herd security over winter. Winter graze was least used in group 6; it is possible that winters were, by this time, becoming too harsh for extended outside grazing. Nevertheless, throughout the occupation, and particularly by group 6, increasing numbers of sheep died following a diet of clean fibrous plants. One explanation is that herders were able to supplement winter graze with hay or cereal fodder, even where winter graze might have been at its most limited, as for group 6. Increasing soft foods by group 6 might indicate that these were also used to supplement winter graze. If this is so, it suggests that resources were always ample enough to fatten winter slaughter herds and that herders managed adequate fodder collection for pre-slaughter feeding.

Examination of *Figure 12.3* reveals the changing resource demands that might have been experienced when more lambs were born in early spring (groups 2 and 3). The introduction of more early births would have lifted pressures on late autumn pastures as the numbers of adults being brought into breeding condition for late births would have fallen; these pastures might have become more available for fattening herds. However, interpretation of the dental microwear evidence points to declining use of pre-death winter graze at this time One

explanation is that any pastures on the fan were reserved for other late autumn uses, and that this situation continued even after the early-birth experiments of groups 2 and 3 were abandoned. A second explanation is that fodder provision was preferred for feeding pre-slaughter herds in winter, as the winter graze was now needed to ensure optimal foetal growth and ewe condition in the increasing number of early-season births. Again, the use of foddering, possibly introduced to facilitate early-season births, was continued after a return of focus to late-season births. Either way, this interpretation suggests resources were available to maintain herd security, but that late autumn fattening and winter feeding of slaughter herds became more reliant on fodder over time.

Summer resourcing is next considered, as the equifinalities of interpretation of the clean fibrous diets demands that they are also considered as representing mature pasture grasses or cereal stubble. The dental microwear evidence shows that their use in feeding slaughter herds just before death increased over time. *Table 12.3* shows that sheep grazing these diets at death could only have been fattened on late spring pastures. It is unlikely that access to these pastures on the fan would have altered with the changing emphasis on birth seasonality, as ewes and lambs in both groups would have needed these nutritious, protected resources. If so, the steady rise in sheep eating clean fibrous diets just before slaughter cannot be explained by increasing slaughter in early summer. It would seem more likely that increasing use of hay or cereal by-product fodder was offered to winter slaughter herds.

The small number of clean soft diets might represent grazing on mature weeds before death rather than eating them as winter fodder. Slaughter herds feeding on these resources would have been fattened on mature pasture grasses beforehand. With the rise in late-season lamb numbers in group 4 onwards (*Figure 11.13*), it is unlikely that these optimal pastures would have become more available on the fan. If so, the rise in sheep eating mature weeds before death might more convincingly reflect a rise in soft-fodder use in herds awaiting early winter slaughter, ensuring that herd security in breeding and growing herds was not undermined.

There is additional evidence, consistent with the implementation of this strategy. Stable carbon isotope evidence suggests that Çatalhöyük sheep had increasing access to halophytic C4 plants from group 2 onwards (Pearson *et al.* 2007). As the dental microwear evidence of C4 grass diets is minimal and non-directional, it is less likely that the perennial halophytic C4 grass, *Aeluropus,* contributed to the C4 signature. However the increasing dietary contribution of clean soft food over time might have included C4 halophytic chenopods, likely to have been present in summer weed vegetation in heavily salinised areas. There is however a proviso to this support for Pearson *et al*.'s (2007) work; dental microwear offers evidence of diet over two or three weeks, whereas carbon stable isotopes provide life-long dietary information.

12.6.3.6. Adjustment to new cattle domesticates

Domestic cattle herds might have been introduced into the Çatalhöyük economy to replace failing sheep herds, to replace the decline in wild hunted herds, or to diversify the domestic food economy; these introductions might have caused competing demands on food resources. It is beyond the scope of this thesis to examine cattle breeding and feeding behaviour in detail, or to model cattle herding at Çatalhöyük, nevertheless some points may be made.

It is interesting to note that the indication of a brief attempt to change the birth season of sheep, or to run two herds with different birth seasons, coincided with the first evidence of early cattle management. It might be presumed that these innovations were related, and that sheep breeding seasonality was adjusted to accommodate new cattle management. Cattle herd security would have needed to establish good yearning rates through optimal seasonal food resourcing. As cattle preferentially graze on taller grasses, and need drinking water, their preferred habitat is wetter than that of sheep; marsh edges on the alluvial fan could have been the most suitable places for their herding at Çatalhöyük. In addition, these newly managed herds might have needed closer protection nearer the settlement. This might

explain why, over time, more sheep awaiting slaughter had their winter graze supplemented with fodder, serving to accommodate cattle herding whilst maintaining sheep herd security.

However, the evidence also suggests that sheep herders might not have continue early-season births, but returned to a late-season focus. The later increase in sheep reliance (*Figure 12.4*) indicates that cattle herds had suffered some failure and were not yet firmly established; it is possible that the benefits of maintaining sheep herd security would have been apparent. If cattle management near the settlement consolidated sheep herding further away wherever possible – for growing juveniles, for ewes in the late stages of gestation and for fattening up sheep destined for slaughter – it is possible to speculate that increasing use of pasturing resources away from the settlement alleviated resource pressures such that it was no longer necessary to manipulate an earlier birth season. Consequently, in groups 4, 5 and 6, herd security might have been maintained by reverting to simpler solutions such as late-season births timed to make maximum use of lowland resources.

12.6.4. Summary

In summary, interpretation of the chronology of oxygen isotope and dental microwear, when understood within modelled herding practices at Çatalhöyük, provides some indications that herders successfully continued to control natural fluctuations in herd size and maintain viable sheep herds until near the end of the Neolithic settlement in Hodder Phase South T, and in the TP Area. Herders were in a position to introduce new measures in South M to Q that facilitated the incorporation of cattle domesticates into the economy, and then successfully re-adjusted their practices in South R and S and in the 4040 Area. If correct, the evidence stands testimony to the robustness of sheep herding practices and to the important, and continuing role they played in Çatalhöyük society.

The evidence suggests that at no time did herders have to resort to more extreme measures, such as herding long distances from the settlement, feeding any of their sheep on leafy

browse fodder or intensifying their product goals. Instead, indications suggest that smaller adjustments were made to meet pressures. Once domestic cattle were introduced during South M, it is argued that a possible brief experiment in manipulating the breeding season was cdv abandoned by the time of South R and the 4040 Area occupation, and instead a greater commitment to keeping certain herd parts away from the settlement, supported by the use of fodder to supplement winter grazing, was enough to re-establish large sheep herds.

The interpreted input of fodder in pre-slaughter dietary regimes is most clearly visible in South M, thereafter steadily rising. Although not radical, the use of fodder nevertheless could have increased the reliance that sheep herders had on arable farming for its by-products, possibly signalling greater integration in the economic sphere at Çatalhöyük.

The first signs of increasing difficulty in maintaining herds emerge in South T and in the TP Area. In support, the Faunal Unit Description for Unit 13545 notes that pathologies on some caprine and cattle bone might indicate some malnourishment at this time (Pawlowskia 2007). However, it is not immediately clear whether attempts were made to manage risk through diversification, or whether organised herding practices were beginning to collapse.

12.7. How was sheep herding organised?

The discussion, so far, has focused on an interpretation of how the needs of sheep were balanced against their exploitation as domesticates. The focus now moves onto the herders and considers how the task of herding was defined and how it was organised. This part of the discussion first asks to what extent herding was separate from other community tasks. Was it the work of specialists? Did it require herders to be away from the settlement for extended periods of the year? Was it closely integrated with crop cultivation? The second set of questions ask how herding was organised within the community. Were sheep considered

to be a shared community resource, their herding organised centrally? Or were they owned by smaller groups such as households, where there was greater autonomy of practice?

In Chapter 6 it was pointed out that only limited analogy can be made to modern herding practices through ethnography, but evidence of herding practices in the Çatalhöyük material culture (*Chapter 3*) and its archaeobotanical record (*Chapter 5*) offers some direction. Oxygen isotope and dental microwear analyses presented in this thesis might add further to interpretation.

12.7.2. How herding was identified

12.7.2.1. Herding as a specialism

Grellier (2006) describes the herder as the guardian of both the sheep and its resources. In order to maintain herd security, whilst meeting product goals, it is necessary to understand sheep breeding cycles, herd splitting requirements, and appropriate levels of protection and food resources. A crucial aspect of the work is the management of the resources; knowledge is needed of the seasonal indicators of the best pastures and when they are under stress; of the seasons when pasture grasses can or cannot benefit from grazing, and of appropriate stocking rates. There is considerable labour investment required to control mating and lambing, to split and move herds and to shepherd the different herd parts. In addition, the herding brief might have included building and maintaining pens, folds and barns, slaughtering and butchering and collecting seasonal fodder. The oxygen isotope and dental microwear evidence suggest that Çatalhöyük herders had the knowledge and labour to successfully effect a complex schedule of seasonal feeding, herd splitting and movement beyond the immediate environs of the settlement. At times during the life of the settlement, the evidence suggests that herders knew how to introduce effective changes in their practices.

Examination of the Çatalhöyük material culture (*Table 3.1*) reveals that the concept of specialisation existed, from the on-site red-stone workshop and off-site at the Kaltepe chipped-stone workshop. Herding some distance from the settlement would isolate herders such that specialist knowledge is necessary to make autonomous decisions, but as the oxygen isotope evidence suggests that almost all herding took place within a few days walk from Çatalhöyük it can be argued that specialism was not a necessity.

Despite likely labour and knowledge demands, there is only one indirect piece of evidence of herding having been a specialisation; some human bodies were wrapped up before burial and were possibly moved some distance to be buried. There were many reasons for people to have been away from Çatalhöyük as they pursued their work, herding is only one of them. However all these bodies were adult males so it is possible that men, not women or children, played a greater role in off-site activities such as herding.

Herding as a distinct identity, that is, as a sphere of knowledge and labour, was surely apparent, yet specialist herders themselves, whether part-time or full-time, cannot be elucidated from the evidence.

12.7.2.2. Herding as a separate activity

Solutions to resource and settlement pressures in many modern societies in southwest Asia include the separation of settled farming and nomadic herding societies; it has been suggested that this might have been practiced as early as the start of the 7th millennium cal. BC in the south Levant settlement of ‘Ain Ghazal (Rollefson & Köhler-Rollefson 1989). As has been discussed above, zooarchaeological and oxygen isotope evidence speak against nomadic pastoralists providing the Çatalhöyük settlement with sheep products.

Separation might, however, have occurred seasonally. In summer, the oxygen isotope suggests that fallow herds – those animals not of immediate use for their products, nor in

need of protection and optimum foods – were not usually taken to mountain pastures some distance from the settlement. In winter, dental microwear interpretation and zooarchaeological body-part evidence points to herds of selected sheep brought close to the settlement for slaughter. Spring was the birthing season, oxygen isotope evidence suggests, where on-site penning and neonate remains indicate close protection of breeding herds near or in the settlement. And in autumn, oxygen isotope evidence suggests that rutting and mating was closely controlled and manipulated, and might imply breeding herds were kept close to the settlement to facilitate this. Throughout the year, it would seem that some herd parts were near the settlement. In support, the use of dung as fuel might indicate herds close to the settlement.

Nevertheless, understood within both oxygen isotope and dental microwear evidence, *Figure 12.3* shows how herd parts might have been seasonally moved off the fan onto grass pastures in other lowland areas, and possibly as far as the terraces; it does not show the movement of fallow herds which might be expected to be away from the fan for most of the year too. Even if all herds were within a few days of Çatalhöyük, it is likely that there were seasonal camps for the herders, sheepfolds for the sheep and barns for the fodder; however these are rarely visible to archaeological survey.

An exception is Pınarbaşı B, close to the bottom of Karadağ Mountain, occupied 200 years before Çatalhöyük was abandoned. Its material culture and the zooarchaeological evidence indicate that Pınarbaşı B might have been a springtime satellite settlement to Çatalhöyük (Carruthers 2003). The oxygen isotope evidence of limited herding in more benign summer conditions (*Table 12.1*) is consistent with its location and hydrology. Dental microwear evidence supports carbon stable isotope analysis of diets increasing in soft forbs (*Figure 11.13*) that might include halophytic chenopods (Pearson *et al.* 2007). The location would also be convenient for sourcing raw volcanic materials for bead production or for milling stones (*Table 3.1*).

More generally, if herders were not specialists, they might be expected to have collected other resources whilst they herded their sheep. On the terrace, xeric trees would have provided fuel as well as nuts and fruit, however there would be less to collect on the treeless plain and sand-ridges. As the evidence points to herders not moving to higher slopes, they would not have had the opportunity for timber collection.

12.7.2.3. Integration with crop cultivation

The modelled evidence shows two reasons why it is likely that herding had some reliance on crop by-products and therefore would have needed a degree of integration with crop production. Firstly, as most of the sheep were not grazing in the hills in summer, unlike their wild progenitors, they would have had to endure a long summer and early autumn on poor nutrition. Secondly, in winter, the concentration of herds awaiting slaughter near the settlement, coupled with the optimal fodder requirements of new cattle herds, would have put pressure on winter graze, especially if the pastures became poached. In both winter and late summer–early autumn, supplementary resources would probably have been necessary and, whilst it is possible that there was ample hay, a fall-back fodder could have been cereal or legume by-products. In summer, cereal stubble might have been grazed too. Fallowed sheep could have subsisted on less nutritious fodder, and it is interesting to note that straw, one such less nutritious fodder, is markedly absent from early brick production (*Table 3.1*).

Archaeobotanical modelling puts forward two possible farming systems, however the Çatalhöyük evidence is, as yet, ambiguous (Bogaard *et al.* 2005). An extensive, arable system requires more land but less labour- intensive farming and would have been suited to the terraces, two or three days from Çatalhöyük. As this system is less dependent on soil-nutrient replacement, herding is modelled as being further removed, except possibly for crop stubble in summer, some winter protection, and crop by-product foddering in winter. Garden farming on manured plots is highly intensive; at Çatalhöyük, better drained areas of the alluvial fan close to the settlement would have been the most likely location. This model

suggests that small caprine herds would be pastured on field edges, early spring tillered crops and late summer stubble.

The oxygen isotope and dental microwear evidence is consistent with the extensive farming model, with the proviso that herd grazing away from the arable fields took place relatively close by in lowland areas. The evidence is less consistent with the garden farming model as a greater reliance on ruderal field edge weeds might be expected to be evident in the dental microwear and, in any case, would not have been nutritious enough to provide the modelled needs of breeding and slaughter herds. Given the modelled size of the Çatalhöyük population and the palaeoenvironmental reconstruction of widespread grasslands on the plain, sand-ridges and terraces, it is argued in this thesis that highly integrated garden farming would have been inadequate and unnecessary at Çatalhöyük.

The dental microwear and oxygen isotope evidence is also consistent with seasonally herding certain animals away from cultivated areas on the grasslands of the plain (only 5km away), the sand-ridge (10km away), or the terrace (20km away). The thesis draws on the Roman model of '*saltus*', or village-based pasture areas on the edge of cultivated lands (Boyazoğlu & Flamant 1990, 377), as the most likely model of herding at Çatalhöyük, and the most parsimonious interpretation of the evidence. It is this system that is used in the neighbouring village of Küçükköy today. This model, of village-edge pasturing, nevertheless involves a degree of integration with the crop cultivators. Interpretation of the evidence suggests that supplementary stubble grazing or straw and chaff foddering would have been seasonally necessary, and that closer supervision of mating and lambing, in particular, would have more easily been conducted closer to the settlement.

As there is no indication of herding specialisation at Çatalhöyük, it is possible that herding and farming were carried out by the same people. The advantages in terms of negotiation – for access to stubble, or collection of fodder or dung – are clear, but the labour scheduling

implications have both advantages and disadvantages. Multi-tasking brings with it certain advantages, but also high labour scheduling demands in certain seasons. Closer to the settlement, labour flexibility would have been greater, where ethnographic information reveals how even the youngest children might help with herding (Beck 1980). Scheduling demands made by crop tending, and the logistical demands made by herd movement, even to village-edge pastures, might have required pooled labour resources. *Table 12.4* illustrates the herding year, based on the modelled evidence.

12.7.3. How herding was organised

The ethnography of settled sheep herding reveals a variety of ways in which herds are organised, ranging from household herding, to neighbourhood collective sharing of tasks, to village-wide centralisation of herds under the care of designated herders (e.g. Barth 1959–60; Forbes 1998; M. Sıvaş & N. Kayan *pers. comm.,* July & August 2007). Herd security might be enhanced by combining herds and enlarging the gene pool. Seasonally, the pattern might change; fallow herding is more likely to be collective and winter care more probably in household-based byres. On a daily basis too, combined ewe and lamb herds might be taken to pasture but returned to household care at night.

Interpretation of Çatalhöyük's architecture and material culture (*Chapter 3*) highlights the household level of production, consumption, exchange and ritual, yet with little individual expression between houses. It is suggested that this reiteration of practices might have served to manage tensions between community and household, not only across the settlement, but also throughout the earlier years of the settlement (Hodder 2006, 53). However, between Hodder Phases O and P (groups 2 and 3 in this thesis) the settlement design, architecture and new mobiliary objects suggest the start of a change to greater household autonomy.

Month	*Herding*			*Herd movement*			*Fodder*		*Slaughter*	*Number of tasks*
	Close herding	*Loose herding*		*Good pasture by settlement*	*Good pasture elsewhere*	*Maintenance pasture*	*Collection*	*Provision*		
January		Early birth ewes	Fallow		Early birth ewes			Yes		4
February		Early birth ewes	Fallow					Yes		3
March	Early births	Late birth ewes	Fallow	Early birthing ewes	Late birth ewes					5
April	Protect lambs	Late birth ewes	Fallow				Legume straw, green weeds			4
May	Late births	Summer slaughter	Fallow	Late birthing ewes	Summer slaughter herd	Early lambs and ewes				6
June	Protect lambs		Fallow	Summer slaughter			Cut hay		Summer slaughter	5
July			Fallow			Late lambs and ewes	Cereal straw	Yes		4
August			Fallow		Early breeding adults		Cereal straw	Yes		4
September	Early rut		Fallow	All early breeding adults				Yes		4
October	Early mating		Fallow		Late breeding adults	All early breeding adults				4
November	Late rut	Winter slaughter	Fallow	All late breeding adults	Winter slaughter		Legume straw			6
December	Late mating		Fallow	Winter slaughter		All late breeding adults		Yes	Winter slaughter	6

Table 12.4
The herding year at Çatalhöyük, based on modelled evidence

It is beyond the scope of this thesis to investigate herd size at Çatalhöyük, but analysis of the oxygen isotope and dental microwear evidence might elucidate aspects of herd organisation, such as any individual, household or neighbourhood autonomy of decision making. The patterning in four cohorts of sheep specimens will be investigated. Firstly, in those from middens associated with neighbourhoods from different households or parts of the settlement (*Chapter 9*); secondly, in the life histories of each sheep; thirdly, in sheep from the interpreted minority groups (those identified in *Chapters 10* and *11* as having less common movement patterns or diets); and fourthly, in the sheep with outlying results (identified in *Chapters 10* and *11*).

The following discussion assumes that the organisation before slaughter and butchery followed through into the organisation of consumption and waste disposal, but it should be borne in mind that organisational structures might have changed at the point of butchery.

12.1.1.1. Household and neighbourhood

The selection of samples does not fully satisfy criteria needed to investigate differences between household neighbourhoods, nor between or areas (*Chapter 9*). In fact, in comparison of the evidence between the neighbourhood of one long-lived building (B65–56–44–10) and that combined from a number of short-lived buildings, both oxygen isotope (*Figures 10.19, 10.23*) and dental microwear evidence (*Figure 11.19*) shows remarkable similarity, and the differences between sheep that might have been raised by occupants in different neighbourhood types are slight. The distribution of birth seasons in both was broadly the same but in the long-lived-building neighbourhood sheep were raised in more uniform conditions during their first year. The diets at death show no discernible differences apart from slightly more clustering in the long-sequence-building neighbourhood. Differences in uniformity suggest that herding might have been organised by neighbourhood but, nevertheless, herding practices followed very similar rules.

Herding organisation might have been by area of the settlement. Whilst spatial comparisons between the South and other Areas produce no clear patterning in birth season, dietary evidence indicates that, compared to the South Area, sheep in other Areas had more access to soft foods, and were not feeding so much on dirty graze. As only the South Area includes sheep from the earlier phases, their apparent greater reliance on dirty graze could be a reflection of later chronological changes in feeding practices. There is the possibility, however, that sheep from different Areas were pastured in different parts of the landscape, where year-round graze was more reliable for South Area sheep.

In short, it would appear that mating and breeding schedules for sheep were managed in similar ways at a settlement level or organisation, but that pasturing, at least for the herds awaiting slaughter, might have been managed at a household level.

12.1.1.2. Life-histories of each sheep

A life-history constructed for each sheep might show the extent to which herding trajectories were determined from the outset, such that any patterning might indicate the degree of autonomy given to different herders. *Table 12. 5* summarises the interpretation of the oxygen isotope and dental microwear evidence for each sheep (*Appendix 26*).

An examination of how birth seasons relate to first year fallow herd movement (*Figure 12.6*) suggests that lambs born in early and mid-spring were either then herded closer to the settlement, by karstic springs or in uphill transhumance, whereas all sheep raised in more shaded places were born in late spring. These results might, however, be due to the disparity in sample size.

Bold numbers = phases used in thesis		*Dental microwear*			
Oxygen isotopes		*Late autumn or winter pasture, muddy or over-stocked*	*Dry mature pasture*	*Mature weeds from summer field-edge , late summer stressed pasture*	*Early spring grass, cereal shoots, reed shoots, green weeds*
First year herding	*Birth*		*Dry, clean hay, cereal stubble, cereal chaff*	*Fodder of weeds or legume straw*	
Movement to higher hills or karstic spring	Early spring April Late spring ?	 **2,2** **4**	**3** **4**	 **5,6**	
Shaded valleys in terraces, lower hills	Early spring April Late spring ?	 **6** **3,5**	 **3,5**	 **1**	
Plain, fan, sand-ridges, terrace	Early spring April Late spring ?	**2,3,1** **1,1,1,2,** **1,1,1,1,1,2,3,3,4,4,5,5,6**	**1,2** **4,6** **3,3,4,4 5,6,6,6,6** **4**	**2,6** **2,4,5,6** **3,4,4,6**	 **5**
(No isotopes)	?	**1,2,2,4,4,5,5,5,6**	**3,4,5,5,**	**3**	

Table 12.5
Summary of herd movement, birth season and diet at death for each Çatalhöyük sheep, identified by its chronological analytical group (bold print)

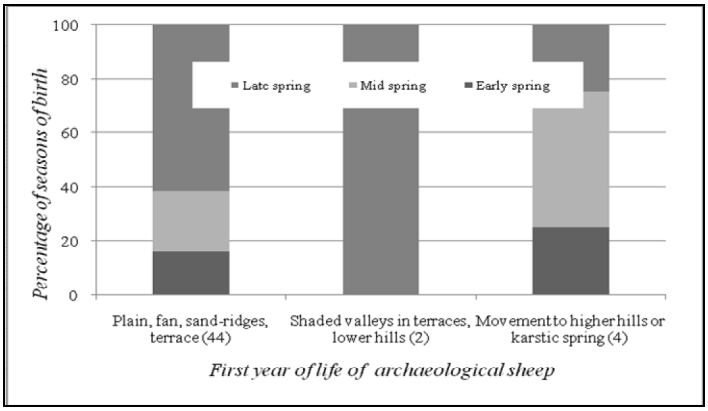


Figure 12.6
Chart showing the relationship between sheep born in different seasons (y-axis) with their movement during their first year (x-axis)

Figure 12.7 restricts itself to the larger sample group of sheep interpreted as having been herded in lowland areas, and displays the relationship between birth season and diets at death. The pattern is remarkably similar in all birth-season groups, suggesting that herding schedules were not pre-arranged from birth.

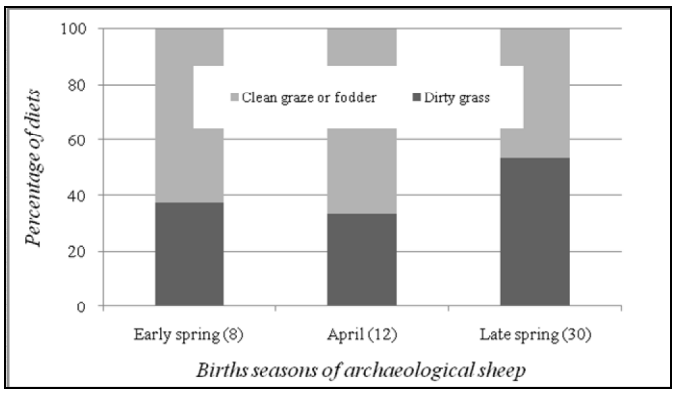


Figure 12.7
Chart showing the relationship between the season in which Çatalhöyük sheep were born (x-axis) and their diets at death (y-axis)

12.1.1.2. Minority groups

Most Çatalhöyük sheep were herded in lowland areas, and most died on grassy diets. There are small groups that are exceptions to this norm in different ways, but that show no

Specimens	*Sample security*	*Phase*	*Neighbourhood*	*House type*	*Oxygen isotope evidence*		*Dental microwear evidence*		
					Birth	*Movement in first year*	*Dirty grass*	*Clean grass*	*Clean weeds or legume by-products*
13	***	2	Other	Other	Late	Movement to higher hills or karstic spring	x		
14	***	2	Other	Other	Late		xx		
23	***	4	Other	x	?		x		
60	***	5	South	Long-lived	?				x
67	***	6	Other	Other	April				x
69	***	4	Other	Other	?			x	
74	***	3	South	Long-lived	Early			x	
30	*	3	South	x	?	Shaded valleys in terraces, lower hills	x		
32	***	6	South	Long-lived	Late		x		
59	***	5	South	Long-lived	?			x	
65	***	1	South	x	Late				x
70	***	5	South	Long-lived	?		x		
75	***	3	South	Long-lived	?			x	

Table 12.6
Summary of all evidence relating to Çatalhöyük sheep raised away from the lowlands during their first year

chronological patterning. They might, however, show interesting consistency in the way they were herded.

The most interesting small group of Çatalhöyük sheep (6) were the ones that have been interpreted as having been raised away from the settlement all year round in more equitable summer conditions consistent with shaded valleys or hillslopes (*Table 12.6*). Although they show no chronological patterning and had different diets before death, the remains of all these sheep were retrieved from middens in the South Area, from the neighbourhood of the long sequence of buildings (B65–56–44–10). Could this house-sequence neighbourhood, uniquely, have had a relationship with a settled satellite community in the foothills of the

mountains surrounding the plain? Did this satellite community contribute sheep to the economy of this long-sequenced building, or did the building act as the place of exchange, where new stock were brought to join Çatalhöyük herds after their first year elsewhere?

The group of sheep (7) that were interpreted as having either experienced some vertical transhumance in summer, or that were pastured near karstic springs, show no patterning in any aspect of their herding, either chronologically or spatially between neighbourhood types or between areas of the settlement, although it might be noted that two are also associated with the long sequence of building neighbourhood mentioned above (*Table 12.6*). It would seem that herders across the settlement had access, albeit limited, to this type of pasturing location.

Specimens	*Security*	*Phase*	*Area of settlement*	*House type*	*Birth season*	*Movement in first year*
2	**	2	South	x	Early	Lowlands
7	*	2	South	x		Lowlands
12	*	6	Other	x		Lowlands
27	*	6	Other	x	Late	Lowlands
39	***	3	Other	Other	Late	Lowlands
40	***	4	Other	Other	Late	Lowlands
41	***	4	Other	Other		Lowlands
60	***	5	South	Long-lived	?	Hills, karstic
62	***	5	South	Long-lived		Lowlands
65	***	1	South	x	Late	Shaded valleys
67	***	6	Other	Other		Hills, karstic
72	***	3	South	Long-lived	?	?

Table 12.7
Summary of all the evidence relating to Çatalhöyük sheep that died having eaten a clean, soft diet

The third group of sheep (13) are the ones that died having eaten clean soft food (*Table 12.7*), already discussed in *Chapter 11*. In addition to showing no chronological patterning, they also show no spatial patterning, and their diets cannot be related to their birth season or first year fallowing.

12.1.1.3. Outliers

In *Chapters 10* and *11*, mention was made of various outliers that emerged during analysis of the data. It is possible that the herding of these sheep was more idiosyncratic, revealing some community tolerance for more individual herding practices (*Table 12.8*). Of the 13 specimens examined, there were none before Phase South M, but 6 from Phase South T and the TP Area, possibly denoting greater herding autonomy later in the occupation. Most outliers (10) came from outside the South Area, and from house- neighbourhoods with shorter occupation sequences, suggesting that these areas and neighbourhoods might have had less rigorous herding rules.

In all other respects there is no patterning within the outlier cohort, but three examples stand out and deserve mention. Specimen 58 is a 3 to 4-year-old sheep that was born very late, in early summer, and died on a particularly soft diet. It is from a Phase South R midden associated with the neighbourhood of the interpreted history house, Building 44. However, it is one of eight from the same midden context and none of the other seven had exceptional life-history indicators. Specimen 14 is a 4 to 6-year-old sheep from a BACH midden associated with a short-sequenced house, and is notable for the dirtiness of its grass-rich diet at death.

Five specimens (9, 12, 26, 27 and 28), in the TP Area, are remarkable for having experienced very cold winters and all, except specimen 9, also experienced very hot summer conditions; there is not enough data to comment on other aspects. Although confirmed as Neolithic, it is unfortunate that all are from more disturbed contexts as it precludes safe

chronological interpretation of this late stage of settlement occupation, at a time of climatic downturn. Nevertheless, the spatial clustering is interesting and might suggest different herding practices in this area of the settlement, where herd protection was not possible or not a priority.

Specimen	*Sample security*	*Phase*	*Area of settlement*	*House type*	*Oxygen isotope outliers*			*Dental microwear outliers*
					Birth month	*First year*	*Protection from seasonal extremes*	
7	*	2	South	x				
9	**	6	Other	x	Late		Cold winter	
12	*	6	Other	x			Hot summer & cold winter	
14	***	2	Other	Other	Late	Hill, karstic		Very dirty grass
26	*	6	Other	x			Hot summer & cold winter	
27	*	6	Other	x	Late		Hot summer & cold winter	
28	*	6	Other	x	Early		Hot summer & cold winter	Dirty soft food
29	*	6	Other	x	Late			
34	*	3	South	x	Late			
36	***	4	Other	Other	Late			
40	***	4	Other	Other	Late		Cold winter	Clean, soft food
41	***	4	Other	Other				
58	***	5	South	Long-lived	Very late			Very soft

Table 12.8

Summary of the evidence relating to all sheep specimens shown to have some outlying data

12.1.2. Summary

In summary, it is argued that Çatalhöyük herders were not a separate section of society, but instead managed their herds either close to, or within a two- or three-day radius of the settlement. At these distances, contact and support between family members, and the

settlement as a whole, could have been maintained relatively easily, as could multi-tasking between herding and other settlement spheres of activity.

There is no evidence of herding having been a specialist occupation, although its tasks would have been labour consuming; the herders might also have been farmers. From Phase South M onwards, the introduction of cattle might have increased competition for land, herding would have been dependent on arable by-products at certain times of the year. Nevertheless, herders appeared to have confirmed a commitment to a late breeding season which would have allowed greater use of the extensive seasonal pastures on the lowlands surrounding the fan, rather than moving the sheep breeding season forward to facilitate field-edge herding.

There are some indications of differences in herding practices between different parts of the settlement and neighbourhood types. In particular, the long-lived-household neighbourhoods might have had their own contacts with satellite herding communities, and might have followed certain herding practices more rigorously than other household neighbourhoods; greater autonomy was also evident away from the South Area. Overall, though, sheep herding appears to have been similar across the settlement and its success in providing for the Çatalhöyük inhabitants, whilst providing the necessary conditions and food resources for healthy herds, suggest a degree of settlement-wide co-ordination.

12.2. What was the place of herders in society?

The Çatalhöyük material culture (*Chapter 3*) gives no direct evidence of herders, although the dung fuel and the consumption remains indicate that herding was an everyday presence in Çatalhöyük society. The evidence presented in this thesis has provided more detail that helps to confirm the continuing success of sheep herding, including its integration with farming. It might be supposed that herding was respected, and its tasks valued, even if not seen as specialist.

The oxygen isotope and dental microwear evidence might provide further indications of how herding might have achieved some status, or even have been the basis of emerging social stratification. The evidence might also indicate to what extent herding played a part in the ritual and social spheres of Çatalhöyük.

12.2.1. Status

Specialisation is an important means of achieving respect and determining status, but there is no evidence of this in the material culture, and the oxygen isotope evidence suggests that it would have been unnecessary for the limited herd movement strategies employed. In addition, the somewhat parochial herding movement would have limited contact with other people and reduce knowledge of the wider landscape and, as such, herding would have had little to offer Çatalhöyük society in terms of networking introductions or new resource locations.

However, the evidence from both datasets shows that Çatalhöyük herders might have introduced innovations in dietary resourcing and in breeding management. As status improves the opportunities for introducing change (Cranstone 1969) it might be argued that the herders did indeed carry significant respect. In addition, the community would have been reliant on sheep herding to provide the greater part of surplus needed to manage stress, and also for social networking and founding new herds. The community might also have perceived herder activity as playing an important role in consolidating a sense of Çatalhöyük territoriality radiating out from the settlement.

12.2.2. Social stratification

Social stratification emerges with wealth accumulation (Halstead 1989), and is most likely to be founded, within a settlement, on asymmetric trajectories between neighbourhoods or settlement areas. Asymmetry might result from group alliances that are successful at the expense of others or, with the number of inhabitants in a group able to share tasks versus the

number of dependents. Struggling groups might call on others for support, resulting in obligations to be fulfilled. Opportunities to divert surplus towards networking, through feasting or gift exchange might consolidate the domination of one group (Halstead 1989).

At Çatalhöyük there are no indications of social stratification, even in later phases where community appears to be giving way to household. The evidence offered in this thesis adds support to this perspective, in that herding strategies are remarkably similar in different areas and different building- neighbourhoods in the settlement, offering less opportunity for stratification to emerge. The exception to this is the neighbourhood of the long sequence of buildings (B66–56–44–10) that extended from Phase South Q to T (assigned by textual notes in the excavation record). Here, the isotope evidence suggests a long relationship with a satellite community located in a more benign setting on lower hillslopes, possibly in a protected valley. Even so, there is no evidence of this relationship having been the foundation for increasing stratification.

12.2.3. Ritual place of herding

The evidence of Çatalhöyük's ritual sphere clearly shows that sheep and sheep herding played virtually no part in its visual representation (*Chapter 3*). Analysis of the spatial distribution of animal and plant remains in burnt buildings also consigns sheep remains to the public sphere of everyday use (Bogaard *et al.* 2009; Twiss *et al.* 2008). There are rare examples where sheep remains have been used in special deposits (Russell & Meece 2005) and one instance where a lamb was carefully interred next to a woman (Russell & Düring 2006). Oxygen isotope and dental microwear analysis of nine specimens found in units described as clusters, feasting remains or bin fills show no patterning which might suggest these sheep were specially reared for ritual use (*Table 12.9*).

There are two arenas in which herding might have influenced ritual thought; in perceptions of human relationship with animals, and with the landscape. There is no direct evidence

from the datasets presented in this thesis that can elucidate these matters. However, the evidence has done much to confirm the close, daily engagement that must have existed between herders and their herds and also the landscape.

Phase	*Specimen*	*Unit*	*Excavation unit description*	*Faunal unit description*	*Birth month*	*Area of 1st year herding*	*Diet before death*
6	29	13098	Cluster in burial	Possibly re-deposited	May	Lowlands	Mature grass, hay, cereal by-products
4	18	11862	Feasting remains	Possibly re-deposited	?	Lowlands	Mature grass, hay, cereal by-products
	19	11897	Feasting remains	Probably re-deposited	X	X	Mature grass, hay, cereal by-products
	16	10264	Cluster	Possibly uncooked sheep	X	X	Dirty grass
3	35	14071	Dump	Unusual body part representation	March	Lowlands	Dirty grass
	30	13370	Cluster behind oven	Possibly curated	?	Shaded valleys	Dirty grass
	38	14800	Infill	Possibly feasting deposit	May	Lowlands	Mature grass, hay, cereal by-products
1	52	1889	Bin fill	Includes articulated unfused bone	April	Lowlands	Dirty grass
	53	1889	Bin fill		June	Lowlands	Dirty grass

Table 12.9
Summary of all evidence relating to specimens found in contexts interpreted as clusters, bins or feasting remains

Orton (2008, 314) speculates that the care invested in herds by their herders might have conflicted with increasing pressures to increase product efficiency that possibly included competition with other herders; he concurs with Russell (2007b, 35) that this conflict might have generated feelings of guilt. Russell (2007b, 35) suggests that guilt might be assuaged through sacrifice; possibly the Çatalhöyük lamb burial is an indicator of this. Whilst Orton (2008, 312) argues that the close animal–human relationship of domestication increased the concept of ownership, Russell (2007b, 35) likens the relationship to a parent's dominance

over a child, introducing the idea of dominance over other humans and the basis, therefore, of social inequality.

Nevertheless, based on interpretation of the evidence presented in this thesis, there was little opportunity for competition, as it is argued that herding was largely a settlement-wide activity. The herders largely succeeded in providing the right conditions for herds to thrive through small changes, and only the interpreted increase in foddering suggests that herders had to give slightly less palatable food to the sheep in their care.

Domestication of the landscape might reduce hunting lands and also enhance a sense of human domination over nature. The effects might be to undermine the traditions and rituals centred on the wild, refocusing beliefs towards ownership and domination. For 1200 years Çatalhöyük herders pastured and moved herds around their landscape and, if the evidence is correct, this activity was confined to the lowland areas within a few days of the settlement; it is likely that the pasturing landscape would have been intimately known and well-trodden. *Table 3.1* shows that, in addition to herding, most resources were retrieved from this same area. It is probable that herding contributed to a greater sense of domination, if not ownership, of the settlement hinterland.

Bogaard and Isaakidou (2010) suggest that Çatalhöyük was a megasite where garden farming continued despite the difficulty of having close access to the arable plots needed for the large population. They argue that garden farming persisted because of a continuing commitment to conservative traditions, and that the changes seen in the material culture (*Chapter 3*) were indicative of this farming system becoming increasingly untenable. The evidence presented in this thesis might indicate, however, that herders were able to adjust their practices by Phase South M, and make use of the surrounding lowland resources within a few days of the settlement. In doing so, conservative traditions were able to loosen without social collapse.

12.2.4. Herding and other settlement changes

There are three points in the chronology of Çatalhöyük where, according to interpretation of the evidence, there might have been changes in sheep herding practice. It is interesting to see whether these coincided with changes observed in the material culture (*Table 3.1)*, and to assess whether they were related in any way.

Unfortunately the observed changes in fuel and timber exploitation during Phase South G are at too fine a resolution for comparison to herding practices; and changes in landscape use cannot be explored. Evidence from this time is limited to settlement-edge activities; it is now that sheep feeding, at least for pre-slaughter herds, was most reliant on winter pasture. The introduction of early ceramics and imported bipolar blades and cores in Phase South H also falls within the earliest group used in this thesis, and so comparisons to herding practices cannot be made.

Between Phases South M–P, the material culture provides the first evidence of mineral tempered pottery and the introduction of unipolar blades. At the same time, the architectural record shows a change to a greater separation of houses alongside imitation replacements of deer teeth ornamentation, the abandonment of bone rings and the appearance of stamp seals and hunting scenes. It is now that early cattle management, sheep herds with a possible earlier breeding season, and the use of supplementary fodder for sheep earmarked for slaughter are first in evidence. It is tempting to see all these changes and innovations as related, part of a cohesive whole.

The suggested successful changes in sheep management that followed, possibly based on a return to a late birthing season that allowed timely seasonal access to food resources, might have provided a sound economic underpinning for society changes to proceed easily. It is possible that the domestic sphere was gaining a more prominent place as interest in past

practices and belief systems waned. The herders' skills, along with skills in other production areas, might have made an increasing contribution to social identity.

Sheep herding continued to provide the greater part of the settlement's meat resources until abandonment and the zooarchaeological record indicates that cattle exploitation never played more than a minor role. Whilst the success of sheep herding might have enabled Çatalhöyük to continue to prosper, it is possible that traditional attitudes to cattle discouraged full diversification into a new domesticated resource. Towards the end of the settlement, there are the first indications that sheep could not be as well husbanded, possibly signalling the detrimental effects of over-reliance on one product.

The ability of herders to manage sheep herds and landscape resources successfully, with the introduction of only small changes, paralleled the small changes observed in the material culture and might have made a significant contribution to the steady evolution of Çatalhöyük society over 1200 years, without recourse to destabilising upheavals. Even while the evidence suggests that herd management might have been under pressure towards the end of the settlement on Çatalhöyük East, the inhabitants were able to continue their reliance on sheep; this might have facilitated a measured relocation to Çatalhöyük West, a few hundred meters away.

12.3. How did herding relate to the outside world?

It is generally agreed that Çatalhöyük was first settled by people bringing domestic caprine herds and crops with them. Developments in the material culture show some clear parallels with the material culture of other southwest Asian settlements and continuing involvement with extensive networks of resource procurement (*Appendices 1–6*). If Çatalhöyük inhabitants were part of a wide social sphere, knowledge of herding practices might also have been exchanged.

The evidence of two separate herds in Phase South M to Q tentatively indicates the introduction of new stock with an earlier birth season. The first evidence of cattle management and the use of fodder supplements at the same time, as well as the new pottery and chipped stone technologies, might confirm powerful outside influences; these might be a new group of settlers or ideas transmitted from southeast Anatolia or the north Levant.

At the same time, the relative isolation of Çatalhöyük, in an optimal setting, might have allowed it to follow its own trajectories with less influence from outside. The evidence presented in this thesis suggests that the settlement might have had highly concentrated control over lowland areas, on and surrounding the Çarşamba alluvial fan, where most sheep were raised locally.

The continuing conservative traditions seen in the settlement plan, the architecture, the commitment to hunting and the reverence for the wild, contrast with development in many settlements in southwest Asia, and have been widely discussed in the literature. The zooarchaeological evidence shows that Çatalhöyük was slow to adopt cattle management in comparison to some north Levantine and east Anatolian settlements in particular, with little evidence of a great commitment to developing this resource.

Sheep continued to be the prime domestic resource, and, as at other central Anatolian settlements, such as Aşıklı and Süberde, there appears to be no pressure to slaughter them immediately on reaching prime meat-bearing age. Although this suggests a sphere of influence operating within central Anatolia, differences in settlement trajectories emerge later in the sequence, with evidence of hunting wild sheep and using the milk and wool of domestic sheep at Erbaba, but not Çatalhöyük.

At the same time, Çatalhöyük forged its identity through its own history, filtering new information from outside through the history of its beliefs and practices, accommodating and

assimilating novel ideas for its own purposes. If, for example, it is correct that herding innovations in breeding manipulation and fodder usage were introduced from outside central Anatolia, it is interesting that the evidence points to herders continuing to supplement graze with fodder, but rejecting breeding manipulation in favour of a late birth season more in tune with seasonal resources widespread in the central Anatolian landscape.

It would seem that there was a complexity of relationships in operation; where Çatalhöyük settlers, partly through their herding practices, expressed their identification with a wide southwest Asia sphere, a more local central Anatolian sphere, and through their own historically and environmentally contingent practices. This interpretation offers support for Asouti's (2006) model of interaction through the construction of settlement identity.

CONCLUSIONS

The aim of this thesis was to provide, from one Neolithic settlement, highly contextual detail of individual sheep at different points in their lives; to assess variation in terms of how the needs of the sheep and the community were met within social and environmental constraints; and to discuss the manner in which herding decisions interfaced with those from other antecedent and coeval settlements.

In this chapter, I present the conclusions drawn from this thesis, discuss possible directions for future work and assess the contribution that my approaches might make to zooarchaeological questions.

13.1. Conclusions to be drawn from the research

13.1.1. Interpretations of herd and resource management

Interpretation of the evidence in *Chapters 10, 11* and *12* allowed preliminary conclusions to be drawn. Firstly, the oxygen isotope evidence suggests that most domestic sheep in the Neolithic settlement of Çatalhöyük, central Anatolia, were born and raised in lowland areas on the alluvial fan, sand-ridges and terraces, and were not taken into the higher mountains as fallow herds in their first year. If this is so, **the first conclusion** is that neither long-distance, seasonal transhumance, nor fully separated, nomadic pastoralism was practiced during the Neolithic at Çatalhöyük.

This conclusion is supported by dental microwear evidence showing most sheep having had access to nutritional graze before death, with no evidence of leafy fodder having been eaten. **The second conclusion** is that, even close to the settlement, resources appear to have been plentiful and so there was neither recourse to stress foddering nor to taking herds far away

from the settlement. If this is so, it is possible that sheep herds were an integrated part of a garden agricultural system.

However, oxygen isotope evidence of birth seasonality points to late spring being the most common birthing season. This birth season synchronises well with suitable graze availability for mating adults, pre-parturition ewes and young lambs, but is less convenient if sheep are dependent on field-edge or fallow graze amongst agricultural plots. If correct, **the third conclusion** is that Çatalhöyük sheep were grazed on dedicated seasonal pastures rather than on less nutritious field-edge weeds needing supplementary fodder.

The dental microwear evidence indicates that very few sheep were feeding on young spring-time graze before death, but most were eating mature dirty graze. **A fourth conclusion** might be drawn: sheep were not slaughtered in spring-time, and most were slaughtered in early winter, after fattening up on autumn grass re-growth.

The conclusions listed above provided the basis for modelling possible seasonal and spatial herd splitting practices within the Çatalhöyük landscape. Modelled seasonal resource availability allowed for some grass pasture on the alluvial fan near the settlement, but it was restricted by human activity that included arable farming, and by areas of marshland unsuitable for sheep. **The fifth conclusion** is that, at any one time of year, one herd part could be kept near the settlement for supervision of mating or lambing, but that other herd parts – both fallow and those being fattened for slaughter – were most probably raised within a system similar to the Roman *saltus*, that is, on the edges of the cultivated landscape, but within a day or two of the settlement.

13.1.2. Interpretations of changing herding practices

The evidence presented in this thesis reveals some indication of temporal changes in both datasets that allow further conclusions to be put forward as possible changes in practices. **The sixth conclusion** is that throughout the Çatalhöyük occupation, herders were able to maintain their herds without recourse to more extreme measures such as fall-back fodder or long-distance herding. Nevertheless, by the end of the settlement in South T and TP Area, there are indications in both datasets that herding strategies included less optimal rearing conditions and fodder provision. **The seventh conclusion** is that herd maintenance had become more difficult by the end of the Neolithic occupation; whether due to collapsing or changing social structures or to climate deterioration associated with the advent of the 8.2k event.

When Çatalhöyük was first settled, dental microwear evidence suggests that almost all sheep were pastured before death, but in the South M Phase the appearance of dry grass diets is interpreted, through resource modelling, as the introduction of supplementary foddering which then steadily increased over time. **The eighth conclusion** is that fodder supplements became more necessary for slaughter herds, possible coinciding with the appearance of domestic cattle herds; if the fodder were cereal chaff and straw, rather than hay, closer integration with arable farming might be indicated.

The oxygen isotope evidence, whilst reliant on very small sample sizes, points to a greater use of an early-spring birthing season earlier in the settlement, although late-spring births still dominated; between South M to Q the evidence might indicate that two herds were being run with different birthing seasons. It is in this period that reliance on sheep was at its lowest. However, by South R there is some indication of a renewed commitment to a late birth season that became greater over time, as did the economic reliance on sheep. **The ninth conclusion,** albeit tentative, is that new stock arrived that birthed in early spring, but

herders' attempts to adopt this birth season, perhaps to allow close integration with the arable schedule or to accommodate new domestic cattle herds, were abandoned in favour of a late birthing season that more closely matched the seasonality of the ample food resources in the landscape.

The interpreted attempts to manipulate the birth seasonality in Çatalhöyük sheep herds coincided with changes in architecture and the chipped-stone and pottery tool-kits (*Chapter 3*) as well as with evidence of the introduction of cattle management (*Chapter 4*). Whilst the changes in material culture closely matched those seen in many mixed agricultural settlements throughout southwest Asia, the domestication of cattle lagged behind (*Chapters 2* and *4*). In addition, interpretation of the evidence in this thesis suggests that Çatalhöyük's inhabitants returned to herding practices that allowed maximum use of the local grasslands. **The tenth conclusion** is that herding played a part in forging the identity of the settlement; herders were possibly willing to be influenced by other settlements in the use of fodder supplements that might suggest greater integration with arable farming, but were able to reject seasonal breeding regimes that undermined the use of the ample landscape resources.

13.1.3. Interpretations of herding organisation

The evidence presented in this thesis suggests there would have been little need for herding to have been a specialist occupation at Çatalhöyük, nevertheless the labour costs and skills required suggest that it was an identifiable, full-time arena of work. In addition, the use of outlying pastures to fallow and fatten herds might indicate that the tasks were undertaken separately from those of agricultural farming, even if not carried out by full-time specialists. **The eleventh conclusion** is that herding was an identifiable task, needing knowledge, time and skill in its organisation, but not necessarily needing specialists in its day-to-day execution.

Herding practices across the settlement were, the evidence suggests, fairly uniform. However, differences emerge in the dental microwear evidence that might indicate some neighbourhood-level organisation, at least for the pasturing of herds awaiting slaughter. **The twelfth conclusion** is that herding might have been organised on a neighbourhood level at certain points but that similar rules were followed across the settlement.

One intriguing difference emerges between short-lived-house neighbourhoods and the long-lived sequence (B65–56–44–10) in the South Area; it is only in the latter that there is evidence of herd movement to other locations. If interpreted correctly, **the thirteenth conclusion** is that the neighbourhood of this long-lived building, with its associated 'history house' (B44), either had a particular relationship with herders in the foothills of nearby mountains, or had exclusive year-round access to such locations.

There is little evidence of the status of herding, apart from that which might have accrued from 1200 years of successfully meeting the needs of the settlement with little recourse to lowering standards of husbandry or altering the level of intensification.

13.2. Assessing the methodologies and models

Standard zooarchaeological interpretation of early herding practices is limited to analyses of on-site assemblages deriving largely from herds earmarked for slaughter. In order to investigate the full extent of herd and resource management practices it is necessary also to investigate the management of animals when they are in breeding herds and being fallowed. Evidence from different stages in individual life-histories of sheep can target periods when each sheep would have been in a breeding herd or have been fallowed. The combination of high resolution oxygen isotope and dental microwear data in tooth enamel begins to redress the gap in zooarchaeological knowledge and, I suggest, promises to be a useful tool in approaching some of the major research question on early herding practices. In order for the

datasets to be understood, robust palaeoenvironmental reconstruction is a vital component, and for discrimination of the results it is necessary for that palaeoenvironment to have marked seasonality and relief.

Domestic sheep in the Neolithic of central Anatolia might be compared to local wild sheep extant in the locality, as they are not likely to have been highly selectively bred. In order to maintain viable herds, the sheep would have needed optimal resources and environmental conditions at certain points in their life-cycle, and also in preparation for slaughter. The ethnographic literature suggests herd splitting onto different pastures is a necessary solution to targeting the best resources to breeding sheep and lambs and to fattening up young adult males for slaughter; meanwhile growing juveniles could be fallowed on maintenance foods, often further away. A full understanding of the physiology requirements of sheep at different stages in their lives offers a way forward in interpreting the oxygen isotope and dental microwear evidence within the palaeoenvironmental seasonal resource models, and also in interpreting archaeobotanic evidence in dung-rich assemblages. I suggest that models of mixed agricultural integration, in particular, can only be fully tested where herd-splitting requirements and food nutrition values have been included.

13.3. Proposals for future research

In my introductory chapter I described two threads to my thesis. The first of these was that the reasons for herding-practice choices made in one settlement might be approached through an assessment of the parallels and differences interpreted in antecedent and coeval settlements. The second thread was that herders would seek the most optimal resources and conditions necessary to maintain herd security, and that models of sheep ethology and palaeoenvironmenal resources might allow highly contextual evidence to be interpreted.

The depth of interpretation allowed by the methodological approach taken to explore the second strand to my thesis reveals that the regional approach taken in the first thread demands similar evidence from a number of sites if fruitful comparisons are to be made. Consequently I have given only limited attention to the first strand of my thesis.

The second thread has produced a number of conclusions that contribute to an understanding of herding in one mixed agricultural setting, as outlined above. It is, however, built on a small, though internally consistent, modern comparator, which unfortunately lacked data from Bozdağ herds. Any expansion of this research, especially if there is to be inter-site comparison, demands a larger modern comparator. In addition the analytical group size used to investigate the chronology seen in the isotope evidence demands that conclusions remain indicative of patterns, where further sampling would be of benefit.

The use of the second mandibular molar alone was, on a reflection, an unnecessary attempt to confine the data context to one tooth. I propose that future work should focus on younger, one- to two-year-old sheep for four reasons. Firstly, at Çatalhöyük at least, this was the peak culling age and the results would more directly relate to slaughter herds. Secondly, the assemblage would be larger, offering a more robust sampling strategy. Thirdly, the second mandibular molar would be fully formed, but only just in wear, allowing a greater column length for sequential sampling. And fourthly, the use of the fourth deciduous pre-molar in the same jaw for microwear analysis in no way undermines interpretation but would enable robust statistical comparison with Mainland's (all references) data, possibly removing some of the equifinalities met in this research.

My research used a multi-disciplinary approach, adding new evidence from two datasets to published zooarchaeological analyses, and then using models of both sheep ethology and palaeoenvironmental resources to interpret that evidence. An extended study could profitably incorporate Pearson's (2010) carbon and nitrogen isotope data, as well as the

carbon stable isotope data generated alongside the oxygen isotope data used in this thesis. These data would add life-long and seasonal dietary signatures that could contribute to elucidating herd management.

An important area of zoological enquiry is one of scale (Halstead 1996), yet the use of standard zooarchaeological methods to establish herd sizes in settlements has met with limited success; this is primarily due to the number of variables that cannot be elucidated. The evidence and approaches that I have used begin to address some of those variables, and might allow plausible models of herd size to be proposed.

13.4. Contributions to zooarchaeological research questions

In this thesis I hoped to expand zooarchaeological knowledge of later Neolithic herding practices and to contribute to some research questions asked by zooarchaeologists working in southwest Asia. I have shown that in one settlement, surrounded by relatively non-degraded grasslands in the benign Neolithic climate, there was no incentive to introduce poor husbandry practices, no need to intensify production and no reason for the society to fission into settled arable and nomadic pastoral components. I have also shown that the use of dedicated pasture on the edges of the cultivated landscape convincingly offers a third model of early mixed agriculture. In addition, good sheep husbandry allowed the settlement to delay changes in its relationship towards other wild species such as cattle, allowing it to maintain its identity within the wider region.

This research has drawn attention to the need for high resolution datasets that can provide details of breeding, movement and feeding throughout the herd animal's life. I suggest that this gap in our understanding can usefully be met with a combination of oxygen isotope and dental microwear analyses, and that herding practices should be interpreted within the modelled ethology of the animal and reconstruction of the settlement palaeoenvironment.

References

Akeret Ö., Haas J., Leuzinger U. & Jacomet S. 1999. Plant macrofossils and pollen in goat/sheep faeces from the Neolithic lake-shore settlement Arbon Bleiche 3, Switzerland. *The Holocene 9*, 175-182.

Akkermans P., van Loon M., Roodenberg J. & Waterbolk H. 1982. The 1976-1977 excavations at Tell Bouqras. *Arabes Syriennes Revue d'Archéologie et d'Histoire Damas 32.*

Akkermans P. & Schwartz G. 2003. *The archaeology of Syria from complex hunter-gatherers to early urban settlements (*ca. *16,000-3,000 BC).* Cambridge: CUP.

Ammerman A. & Cavalli-Sforza L. 1973. A population model of the diffusion of early farming in Europe. In (Ed.) Renfrew C. *The explanation of cultural change: models in Prehistory.* London: Duckworth, 343-357.

Anderson S. & Ertuğ-Yaraş F. 1998. Fuel, fodder and faeces: an ethnographic and botanical study of dung fuel use in Central Anatolia. *Environmental Archaeology 1,* 99-109.

Andrews P., Molleson T. & Boz B. 2005. The human burials at Çatalhöyük. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 261-278.

Andrzejewska L. & Gyllenberg G. 1980. Small herbivore subsystems. In (Eds.) Breymeyer A. & van Dyne G. *Grasslands, systems analysis and man*. Cambridge: CUP, 201-268.

Arbuckle B. 2008ba. Revisiting Neolithic caprine exploitation at Süberde, Turkey. *Journal of Field Archaeology 33,* 219-236.

Arbuckle B. 2008b. Caprine exploitation at Erbaba Höyük: a Pottery Neolithic village in central Anatolia. In (Eds.) Vila E., Gourichon L., Choyke A. & Buitenhuis H. *Archaeozoology of the Near East VIII.* Lyon: Maison de l'Orient et de la Méditerrrané, 345-365.

Arbuckle B. & Makarewicz C. 2009. The early management of cattle (*Bos taurus*) in Neolithic central Anatolia. *Antiquity 83,* 669-686.

Arbuckle B., Őztan A. & Gülçur S. 2009. The evolution of sheep and goat husbandry in central Anatolia. *Anthropozoologica 44,* 129-157.

Arnold E. & Greenfield H. 2006. The origins of transhumant pastoralism in temperate southeastern Europe. *British Archaeological Reports (International Series) 1538.*

Asouti E. 2005. Woodland vegetations and the exploitation of fuel and timber at Neolithic Çatalhöyük: report on the woo-charcoal macro-remains. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 213-258.

Asouti E. 2006. Beyond the Pre-pottery Neolithic B interaction sphere. *Journal of World Prehistory 20*, 87-126.

Asouti E. & Fairbairn A. 2002. Subsistence economy in Central Anatolia during the Neolithic: the archaeobotanical evidence. In (Eds.) Gérard F. & Thissen L. *The Neolithic of Central Anatolia: Central Anatolia Neolithic e-Workshop (CANeW) table ronde* Istanbul: Ege Yayınları, 181-192.

Asouti E. & Hather J. 2001. Charcoal analysis and the reconstruction of ancient woodland vegetation in the Konya Basin, south-central Anatolia, Turkey: results from the Neolithic site of Çatalhöyük East. *Vegetation History and Archaeobotany 10***,** 23-32.

Atalay S. 2005. Domesticating clay: the role of clay balls, mini balls and geometric objects in daily life at Çatalhöyük. In (Ed.) Hodder I. Changing *materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 139-169.

Aurenche O., Galet P., Régagnon C. & Évin J. 2001. Proto-Neolithic and Neolithic cultures in the Middle-East – the birth of agriculture, livestock-raising, and ceramics: a calibrated ^{14}C chronology 12,500–5500 cal. BC. *Radiocarbon 43*, 119-1202.

Aydinoğlugil B. 2000. (Unpublished MSc Dissertation). *Reviewing the sheep bones from Çatalhöyük in the light of information on Middle Anatolian Neolithic sites and the* Ovis orientalis *in Konya, Bozdağ.* London: Institute of Archaeology, UCL.

Ayliff L. & Chivas A. 1988. Australian macropods (kangaroos and wallabies): palaeoenvironmental potential of bone phosphate oxygen isotopes. *Chemical Geology 70*, 114.

Bailey L. 1980. *If you take my sheep*. Pasadena, California: Westernlore Publications.

Bains R. & Wright K. 2008. Stone bead technology at Çatalhöyük. *Çatalhöyük 2008 archive report*. www.catalhoyuk.com, 240-242. (Retrieved on 09.07.09).

Baird D. 1997. Goals in Jordanian Neolithic research. In (Eds.) Gebel H., Kafafi Z. & Rollefson G. *The prehistory of Jordan, II: perspectives from 1997.* Studies in early Near Eastern production, subsistence, and environment 4. Berlin: Ex Oriente, 371-381.

Baird D. 2005. The history of settlement and social landscapes in the Early Holocene in the Çatalhöyük area. In (Ed.) Hodder I. *Çatalhöyük perspectives: themes from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 55-74.

Baird D. 2006. The Boncuklu project: the origins of sedentism, cultivation and herding in Central Anatolia. *Anatolian Archaeology 12*, 13-16.

Baird D. 2007. The Boncuklu project: the origins of sedentism, cultivation and herding in Central Anatolia. *Anatolian Archaeology 13*, 14-17.

Baird D. 2008. The Boncuklu project: the origins of sedentism, cultivation and herding in Central Anatolia. *Anatolian Archaeology 14,* 11-12.

Baird D. 2009. The Boncuklu Project: investigating the beginnings of agriculture, sedentism and herding in central Anatolia. *Anatolian Archaeology 15,* 9-10.

Baker G., Jones L. & Wardrop I. 1959. Cause of wear in sheeps' teeth *Nature 184,* 1583-1584.

Baker J. & Brothwell D. 1980. *Animal diseases in archaeology.* New York: Academic Press.

Balasse M. 2002. Reconstructing dietary and environmental history from enamel isotopic analysis: time resolution of intra-tooth sequential sampling. *International Journal of Osteoarchaeology 12,* 155-165.

Balasse M. 2003. Potential biases in sampling design and interpretation of intra-tooth isotope analysis. *International Journal of Osteoarchaeology 13,* 3-10.

Balasse M. & Ambrose S. 2005. Distinguishing sheep and goats using dental morphology and stable carbon isotopes in C_4 grassland environments. *Journal of Archaeological Science 32,* 691-702.

Balasse M., Ambrose S., Smith A. & Price D. 2002. The seasonal mobility model for prehistoric herders in the south-west Cape of South Africa assessed by isotopic analysis of sheep tooth enamel. *Journal of Archaeological Science 29,* 917-932.

Balasse M., Smith A., Ambrose S. & Leigh S. 2003. Determining sheep birth seasonality by analysis of tooth enamel oxygen isotope ratios: the Late Stone Age site of Kasteelberg (South Africa). *Journal of Archaeological Science 30,* 205-215.

Balasse M. & Tresset A. 2002. Early weaning of Neolithic domestic cattle (Bercy, France) revealed by intra-tooth variation in nitrogen isotope ratios. *Journal of Archaeological Sciences 29,* 853-859.

Balasse M. & Tresset A. 2007. Environmental constraints on the reproductive activity of domestic sheep and cattle: what latitude for the herder? *Anthropozoologica 42,* 71-87.

Balıkcı A. 1990. Tenure and transhumance: stratification and pastoralism among the Lankenkhel. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 301-322.

Bar-Matthews M., Ayalon A., Gilmour M., Matthews A. & Hawkesworth C. 2003. Sea-land oxygen isotopic relations from planktonic foraminifera and speleotherms in the eastern Mediterranean region and their implication for paleorainfall during interglacial intervals.*Geochimica et Cosmochimica Acta 67,* 3181-3199.

Bar-Matthews M., Ayalon A. & Kaufman A. 1997. Late Quaternary palaeoclimate in the eastern Mediterranean region from stable isotope analysis of speleotherms at Soreq Cave, Israel. *Quaternary Research 47,* 155-168.

Barth F. 1959-1960. The land use pattern of migratory tribes of South Persia. *Norsk Geografisk Tidsskrift 17,* 1-4.

Barth F. 1961. *Nomads of South Persia: the Basseri tribe of the Khamseh Confederacy*. London: George Allen & Unwin Ltd.

Bartolomé J., Franch J., Plaixats J. & Seligman N. 1998. Diet selection by sheep and goats on Mediterranean heath-woodland range. *Journal of Range Management 51,* 383-391.

Bar-Yosef O. 2001. From sedentary foragers to village hierarchies: the emergence of social institutions. *Proceedings of the British Academy 110,* 1-38.

Bar-Yosef O. & Belfer-Cohen A. 1989. The Levantine 'PPNB' interaction sphere. In (Ed.) Hershkovitz I. *People and culture in change.* British Archaeological Reports (International Series) 508, 59-72.

Bar-Yosef O. & Belfer-Cohen A. 1991. From sedentary hunter-gatherers to territorial farmers in the Levant. In (Ed.) Gregg S. *Between bands and states.* Southern Illinois University: Centre for archaeological investigations, 181-202.

Bayliss A. & Farid S. 2008. Re-assessment of the existing dating of the East Mound – a progress report. *Çatalhöyük 2008 archive report.* www.catalhoyuk.com, 281-282. (Retrieved on 23.06.09).

Baysal A. & Wright K. 2005. Cooking, crafts and curation: ground-stone artefacts from Çatalhöyük. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 307-324.

Beck L. 1980. Herd owners and hired shepherds: the Qasha'i of Iran. *Ethnology 19,* 327-351.

Beck L. 1991. *Nomad: a year in the life of a Qashqa'i tribesman in Iran*. Berkley: University of California Press.

Bentley R. & Knipper C. 2005. Geographical patterns in biologically available strontium, carbon and oxygen isotope signatures in prehistoric SW Germany. *Archaeometry 47,* 629-644.

Bentley R., Krause R., Price T. & Kaufmann B. 2003. Human mobility at the early Neolithic settlement of Vaihingen, Germany: evidence from strontium isotope analysis. *Archaeometry 45,* 471-468.

Bentley R., Pietrusewskly M., Douglas M. & Atkinson T. 2005 Matrilocality during the Prehistoric transition to agriculture in Thailand. *Antiquity79,* 865-881.

Bentley R., Price T. & Stephan E. 2004. Determining the local $^{86/87}$Sr range for archaeological skeletons: a case study from Neolithic Europe. *Journal of Archaeological Sciences 31,* 365-375.

Bernus E. 1990. Dates, dromedaries and drought: diversification in Tuareg pastoral systems. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 149-176.

Betts A. 1993. The Neolithic sequence in the east Jordan *badia.* A preliminary overview. *Paléorient 19,* 43-53.

Betts A. 2001. Pastoralism. In (Eds.) MacDonald B., Adams R. & Bienkowski P. *The Archaeology of Jordan.* Sheffield: Sheffield Academic Press, 615-619.

Beuls I. 2004. (Unpublished PhD thesis). *Design of odontological tool to elucidate small ruminant herd management at Sagalassos (SW Turkey) in Roman-Byzanine Period (0-650 AD).* Catholic University of Leuven.

Beuls I., de Cupere B., van Merle P., Vermoere M. & Waelkens M. 2000a. Present-day traditional ovicaprine herding as a reconstructional aid for understanding herding at Roman Sagalassos. In (Eds.) Mashkour M.; Choyke A., Buitenhuis H. & Poplin F. *Proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas*. Groningen: ARC Publications 32, 216-223.

Beuls I., de Cupere B., Vermoere M., Vanhecke L., Doutrelepont H., Vrydaghs L., Librecht I. & Waelkens M. 2000b. Modern sheep and goat herding near Sagalassos and its relevance to the reconstruction of pastoral practices in Roman times. In (Eds.) Waelkens M. & Poblome J. *Sagalassos V report on the survey and excavation campaign of 1996*. Leuven: Leuven University Press, 847-861.

Beuls I., Vanhecke L., de Cupere B., Vermoere M., van Neer W. & Waelkens M. 2002. The predictive value of dental microwear in the assessment of caprine diet. In (Eds.) Buitenhuis H., Choyke A., Mashkour M. & Al Shiyab H. *Archaeozoology of the Near East V.* Proceedings of the Fifth International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas. Groningen: ARC–Publication 62, 337-355.

Bickle P. & Hofmann D. 2007. Moving on: the contribution of isotope studies to the early Neolithic of Central Europe. *Antiquity 81,* 1029-1041.

Billet G., Blondel C. & de Muizon C. 2009. Dental microwear analysis of notoungulates (Mammalia) from Salla (Late Oligocene Bolivia) and discussion on their precocious hypsodonty. *Palaeogeography, Palaeoclimatology, Paaleoecology 274,* 114-124.

Binford L. 1978. *Nunamiut Ethnoarchaeology.* New York: Academic Press.

Blisniuk P. & Stern L. 2005. Stable isotope paleoaltimetry: a critical review. *American Journal of Science 305,* 1033-1074.

Bocherens H., Mashkour M., Billou D., Pellé E. & Mariotti A. 2001. A new approach for studying prehistoric herd management in arid areas: intra-tooth isotopic analyses of archaeological caprine from Iran. *Earth and Planetary Sciences 322,* 67-74.

Boessneck J. 1969 (2nd edition). Osteological differences between sheep (*Ovis aries* Linne) and Goat (*Capra hircus* Linne). In (Eds.) Brothwell D. & Higgs E. *Science in Archaeology.* London, 331-358.

Bogaard A. 2005. 'Garden agriculture' and the nature of early farming in Europe and the near East. *World Archaeology 37,* 117-196.

Bogaard A., Charles M., Ergun M., Ertuğ F. & Filipović D. 2008. Macro botanic remains 2008 – study of botanical inclusions in mudbrick. *Çatalhöyük 2008 archive report.* www.catalhoyuk.com 43-52. (Retrieved on 24.07.09).

Bogaard A., Charles M., Livarda A., Ergun M., Filipovic D. & Jones G. 2010 (Manuscript). *Preliminary summary of archaeobotanical results.*

Bogaard A., Charles M., Twiss K., Fairbairn A., Yalman N., Filipović D., Deirergi A., Ertuğ F., Russell N. & Henecke J. 2009. Private pantries and celebrated surplus: storing and sharing food at Neolithic Çatalhöyük, Central Anatolia. *Antiquity 83,* 649-668.

Bogaard A. & Isaakidou V. 2010. From mega-sites to farmsteads; community size, ideology and the nature of early farming landscapes in western Asia and Europe. In (Eds.) Finlayson B. & Warren G. *Landscapes in transition.* Oxford: Oxbow Books, 192-207.

Bogaard A., Jones G. & Charles M. 2005. The impact of crop processing on the reconstruction of crop sowing time and cultivation intensity from archaeobotanic weed evidence. *Vegetation History Archaeobotany 14,* 505-509.

Bökönyi S. 1977. *The animal remains from four sites in the Kermanshah valley, Iran: Asiab, Sarab, Dehsavar and Siahbid.* British Archaeological Reports (Supplementary Series) 34.

Bordaz J. 1969. The Süberde excavations, Southwestern Turkey. An Interim Report, *Türk Arkeoloji Dergisi 17*, 43-71.

Bordaz J. & Bordaz L. 1982. Erbaba: the 1977 and 1978 seasons in perspective. *Türk Arkeoloji Dergesi 26,* 85-92.

Bottema S. & Woldring H. 1984. Late quaternary vegetation and climate of southwestern Turkey.Part II. *Paleohistoria* 26, 123-149.

Bourdieu P. 1977. *Outline of a theory of practice*. Cambridge: Cambridge University Press.

Boyazoğlu J. & Flamant J-C. 1990. Mediterranean systems of animal production. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 353-393.

Boyer P., Roberts N. & Baird D. 2006. Holocene environment and settlement on the Çarşamba alluvial fan, South-Central Turkey: integrating geoarchaeological and archaeological field survey *Geoarchaeology 21,* 675-698.

Braidwood R. 1983. Miscellaneous analyses of materials from Jarmo: *Prehistoric archaeology along the Zagros flanks.* Chicago: Oriental Institute Publications.

Braidwood R. & Howe B. 1960. *Prehistoric investigations in Iraqi Kurdistan*. Chicago: University of Chicago.

Brain C. 1981. Parts of the skeleton: survival and disappearance. In (Ed.) Brain C. *The hunters or the hunted? An introduction to African cave taphonomy*. Chicago: University of Chicago Press, 11-27.

Braun E. 1997. *Yiftah'el: salvage and rescue excavations at a prehistoric village in Lower Galilee, Israel.* Jerusalem: Israel Antiquities Authority.

Britton K., Grimes V., Dau J. & Richards M. 2009. Reconstructing faunal migrations using intra-tooth sampling and strontium and oxygen isotope analyses: a case study of modern caribou. (*Rangifer tarandus granti*). *Journal of Archaeological Science 36,* 1163-1172.

Brochier, J. 1993. Çayönü Tepesi. Domestication, rythmes et environment au PPNB. *Paléorient 19,* 39-49.

Brochier J., Vill P. & Giacomarra M. 1992. Sheep and sediments; geo-ethnoarchaeology of pastoral sites. *Journal of Anthropological Archaeology 11,* 47-102.

Browman D. 1990. High altitude camelid pastoralism of the Andes. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 323-352.

Bruford M. & Townsend S. 2006. Mitochondrial DNA diversity in modern sheep: Implications for domestication. In (Eds.) Zeder M., Emshwiller E., Smith B. & Bradley D. *Documenting domestication*. Berkeley: University of California Press, 306–316.

Bryant J. & Froelich P. 1995. A model of oxygen isotope fractionation in body water of large mammals. *Geochimica et Cosmochimica Acta 59.* 4523-4537.

Buitenhuis H. 1985. Preliminary report on the faunal remains of Hayaz Höyük from the 1979-1983 seasons. *Anatolica 13,* 61-74.

Buitenhuis H. 1997. Aşıklı Höyük: a 'protodomestication' site. *Anthropozooligca* 25, 655-662.

Buitenhuis H. 2001. *Musular: the first results of the analysis of the faunal remains.* Unpublished field report.

Byrd B. 1992. The dispersal of food production across the Levant. In (Eds.) Gerbauer A. & Price T. *Transitions to agriculture in prehistory: Monographs in world archaeology 4.* Madison: Prehistory Press, 49-61.

Çambel H. & Braidwood R. 1980. *Prehistoric research in southeast Anatolia.* Istanbul: Edebiyat Fakultesi Basımevi.

Campbell D. 2010. Modelling the agricultural impacts on the earliest large villages at the Pre-pottery Neolithic - Pottery Neolithic transition. In (Eds.) Finlayson B. & Warren G. *Landscapes in Transitiion.* Oxford: Oxbow, 173-183.

Canti M. 1999. The problem and preservation of faecal spherulites: animals, environment and taphonomy. *Journal of Archaeological Science 26*, 251-258.

Capper S. 1990. The role of food legume straw and stubble in feeding livestock. In (Eds.) Osman A., Ibrahim M. & Jones M. *The role of legumes in the farming systems of the Mediterranean areas.* Dordrecht: Kluwer Academic Publishers, 151-162.

Carruthers D. 2003. (Unpublished PhD thesis) *Hunting and herding in Central Anatolian prehistory: the 9th and 7th millennium site at Pınarbaşı.* Department of Archaeology: Edinburgh University.

Carter T., Conolly J. & Spasojević A. 2005a. The chipped stone. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 221-284.

Carter T., Poupeau G., Bressy C. & Pearce N. 2005b. From chemistry to consumption: towards a history of obsidian use at Çatalhöyük through a programme of inter-laboratory trace-elemental characterization. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 285-306.

Cassidy J. 2008. *Clay stamp report*. Çatalhöyük 2008 archive report. www.catalhoyuk.com, 204-208. (Retrieved on 16.07.09).

Castri F. 1981. Mediterranean-type shrublands of the world. In (Eds.) Castri F., Goodall D.& Specht R. *Mediterranean-type shrublands. Ecosystems of the World.* Amsterdam: Elsevier Scientific Publishing Company, 1-52.

Çatalhöyük Research Project. 2009. *Database.* www.catalhoyuk.com. (Retrieved on 12. 12. 09).

Cauvin J. 2000. *The birth of the gods and the origins of agriculture*. Cambridge: Cambridge University Press.

Cavallo C. 2000. *Animals in the steppe: a zooarchaeological analysis of the Later Neolithic Tell Sabi Abyad, Syria*. British Archaeological Reports (International Series) 891.

Cessford C. 2001. A new dating sequence for Çatalhöyük. *Antiquity 75*, 717-725.

Cessford C. 2005a. Absolute dating at Çatalhöyük. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* Cambridge & Ankara: McDonald Institute for Archaeological Research, British Institute at Ankara, 65-100.

Cessford C. 2005b. Estimating the Neolithic population of Çatalhöyük. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 323-329.

Chang C. & Koster H. 1986. Beyond bones: toward an archaeology of pastoralism. *Advances in Archaeological Method and Theory 9*, 97-148.

Charles M. 1998. Fodder from dung: the recognition and interpretation of dung-derived plant material from archaeological sites. *Environmental Archaeology 1*, 111-122.

Clarke J. 2007. *On the margins of southwest Asia: Cyprus during the 6th to 4th millennia BC*. Oxford: Oxbow.

Clason A. 1979-80. The animal remains from Tell es Sinn compared with those from Bouqras. *Anatolica 7*, 35-54.

Clutton-Brock J. 1979. The mammalian remains from the Jericho Tell. *Proceedings of the Prehistoric Society 45*, 135-157.

Clutton-Brock J. 1994. The unnatural world: behavioural aspects of humans and animals in the process of domestication. In (Eds.) Manning A. & Serpell J. *Animals and human society: changing perspectives.* London: Routledge, 23-35.

Cohen H. & Erol O. 1969. Aspects of the Palaeogeography of Central Anatolia. *The Geographical Journal 135*, 388-398.

COHMAP Members. 1988. Climate change of the last 18,000 years: observations and model simulations. *Science 241*, 1043-1052.

de Conteson H. 1983. Early agriculture in western Asia. In (Eds.) Young D., Smith P. & Mortenson P. *The hilly flanks and beyond*. Chicago: The Oriental Institute of the University of Chicago, 57-74.

Copley M., Clark K. & Evershed R. 2005. Organic residue analysis of pottery vessels and clay balls. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 169-174.

Costin C. 1991. Craft specialization: issues in defining, documenting, and explaining the organisation of production. *Archaeological Method and Theory 3*, 1-56.

Courty M., MacPhail R. & Wattez J. 1991. Soil microphological indicators of pastoralism; with special reference to Arene Candide, Finale Ligure, Italy. *Rivista di Studi Liguri, A. LVII,1-4*, 127-150.

Craig H. 1961. Isotopic variations in meteoric waters. *Science 133*, 1702-1703.

Cranstone B. 1969. Animal husbandry: the evidence from ethnography. In (Eds.) Ucko P. & Dimbleby G. *The domestication and exploitation of plants and animals.* London: Duckworth, 247-264.

Cribb R. 1991. *Nomads in archaeology*. Cambridge: CUP.

Curtis J. & Hodell D. 1993. An isotopic and trace element study of ostracods from Lake Miragoane, Haiti: a 10,500 year record of paleosalinity and paleotemperature changes in the Caribbean. In (Eds.) Swart P., Lohmann K., McKenzie J. & Savin S. *Climate changes in continental isotopic records*. Washington: American Geophysical Union, 135-152.

Cutting M. 2005. The architecture of Çatalhöyük: continuity, households and the lost upper levels. In (Ed.) Hodder I. *Çatalhöyük perspectives: themes from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 151-170.

Dahl G. & Hjort A. 1976. *Having herds: pastoral herd growth and household economy.* Stockholm: Stockholm Studies in Social Anthropology.

van Dam J. & Reichart G. 2009. Oxygen and carbon isotope signatures in late Neogene horse teeth from Spain and their application as temperature and seasonality proxies. *Palaeogeography, Palaeoclimatology, Palaeoecology 274,* 64-8.

D'Angela D. 1991. Palaeoclimatic conditions in the Po plain during the Neolithic, Chalcolithic and Bronze Ages:first results. *Rivista di Studi Liguri A, 57,* 119-126.

D'Angela D., & Longinelli A. 1990. Oxygen isotopes in living mammal's bone phosphate: further results, *ChemicalGeology (Isotope Geoscience Section)* 86, 75-82.

Dansgaard W. 1964. Stable isotopes in precipitation. *Tellus 16,* 436-468.

Darling W., Bath A., Gibson J. & Rozanski K. 2006. Isotopes in water. In (Ed.) Leng M. *Isotopes in palaeoenvironmental research.* The Netherlands: Springer, 1-66.

Davis S. 1984. Khirokitia and its mammal remains: a Neolithic Noah's ark. In (Ed.) Le Brun A. *Fouilles récentes à Khirokitia,(Chypre) 1977-1981.* Paris: Edition Recherche sur les Civilisations, 147-162.

Day R., Laland K. & Odling-Smee. 2003. Rethinking adaptation: the niche construction perspective.*Perspective in Biology and Medicine. 46,* 80-95.

Delgado Huertas A., Iacumin P., Stenni B., Sanchez-Chillon B. & Longinelli A. 1995. Oxygen isotope variations of phosphate in mammalian bone and tooth enamel. *Geochimica et Cosmochimica Acta 59,* 4299-430.

Dixon J., James D. & Sherman P. 1989. *The economics of dryland management.* London: Earthscan Publications.

Doherty C. 2010 (manuscript). *Sourcing Çatalhöyük's clays*.

Doherty C., Charles M. & Bogaard A. 2007. Preliminary sediment coring to clarify 'clay' sources and potential land use around Çatalhöyük. *Çatalhöyük 2007 archive report.* Çatalhöyük research project.www.catalhoyuk.com 382-392. (Retrieved on 06.03. 10).

Doherty C., Charles M. & Bogaard A. 2008. Landscape coring. *Çatalhöyük 2008 archive report.* Çatalhöyük research project. www.catalhoyuk.com 263-272. (Retrieved on 06.03. 10).

Donovan P. 2005. A note on modelling field location. In (Ed.) Hodder I. *Çatahöyük perspectives: reports from the 1995-1999 seasons*. Cambridge & Ankara: McDonald Institute for Archaeological Research &British Institute at Ankara, 51-53.

von den Driesch A. & Wodtke U. 1997. The fauna of 'Ain Ghazal, a major PPN and early PN settlement in Central Jordan. In (Eds.) Gebel H., Kafafi Z. & Rollefson G. *The prehistory of Jordan, II. Perspectives from 1997. Studies in early Near Eastern production, subsistence and environment 4.* Berlin: ex oriente, 511-555.

Driessen P. & de Meester T. 1969. *Soils of the Çumra area, Turkey.* Wageningen: Centre for Agricultural Publishing and Documentation.

Ducos P. 1988. *Archaeozoologie quantitative – les valeurs numériques immediates à Çatal Huyuk.* (Les Cahiers du Quaternaire 12). Paris: Éditions du Centre Nationale de la Recherche Scientifique.

Ducos P. 1993. Some remarks about *Ovis, Capra* and *Gazella* remains from two PPNB sites from Damascene, Syria, Tell Aswad and Ghoraifé. In (Eds.) Buitenhuis H. & Clason A. *Archaeozoology of the Near East: proceedings of the first symposium on the archaeozoology of Southwestern Asia and adjacent areas.* Leiden: Backhuys, 37-45.

Düring B. 2005. Building continuity in the central Anatolian Neolithic: exploring the meaning of building at Aşıklı Höyük and Çatalhöyük. *Journal of Mediterranean Archaeology 18,* 3-29.

Düring B. 2007. Reconsidering the Çatalhöyük community: from households to settlement systems. *Journal of Mediterranean Archaeology 20,* 155-182.

Düring B. & Marciniak A. 2005. Household communities in the central Anatolian Neolithic. *Archaeological Dialogues 12,* 165-187.

Duru G. 2002. Some architectural indications for the origins of Central Anatolia. In (Eds.) Gérard F. & Thissen L. *The Neolithic of Central Anatolia: Central Anatolia Neolithic e-Workshop (CANeW) table ronde.* Istanbul: Ege Yayınları, 171-180.

Edelberg L. 1966/67. Seasonal dwellings of farmers in North-Western Luristan. *Folk 8/9,* 373-401.

Edwards T. 1993. Interpreting past climate from stable isotopes in continental organic matter. In (Eds.) Swart P., Lohmann K., McKenzie J. & Savin S. *Climate changes in continental isotopic records. Geophysical monograph 78.* Washington: American Geophysical Union, 333-342.

Ellis R. & Voigt M. 1981. Excavations at Gritille, Turkey: 1981. *Paléorient 7,* 87-100.

Emeis K-C., Struck U., Schulz H-M., Rosenberg R., Bernasconi S., Erlenkeuser H., Sakamoto T. & Matinez-Ruiz F. 2000. Temperature and salinity variations of Mediterranean Sea surface waters over the last 16,000 years from records of planktonic stable oxygen isotopes and alkenone unsaturation ratios. *Palaeogeography, Palaeoclimatology, Palaeoecology 158,* 259-280.

Ertuğ-Yaraş F. 1997. (Unpublished PhD thesis). *An ethnoarchaeological study of subsistence and plant gathering in Central Anatolia*. Department of Anthropology, Washington University.

Esin U. 1999. Introduction: the Neolithic in Turkey: a general review. In (Eds.) Özdoğan M. & Başgelen N. *Neolithic in Turkey: the cradle of civilization.* Istanbul: Arkeoloji ve Sanat Yayınları, 13-23.

Esin U. & Harmankaya S. 1999. Aşıklı. In (Eds.) Özdöğan M. & Başgelen N. *Neolithic in Turkey in the cradle of civilization.* Istanbul: Arkeoloji ve Sanat Yayınları, 115-132.

Evershed R., Payne S., Sherratt A., Copley M., Coolidge J., Urem-Kotsu D., Kotsakis K., Özdoğan M., Özdoğan A., Nieuwenhuyse O., Akkermans P., Bailey D., Andeescu R-R., Campbell S., Farid S., Hodder I., Yalman N., Özbaşaran M., Bıçakı E., Garfinkel Y., Levy T. & Burton M. 2008. Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature 455,* 528–531.

Fairbairn A. 2005. A history of agricultural production at Neolithic Çatalhöyük East, Turkey. *World Archaeology 37,* 197-210.

Fairbairn A., Asouti E., Near J. & Martinoli D. 2002. Macro-botanical evidence for plant use at Neolithic Çatalhöyük, south-central Anatolia, Turkey. *Vegetation History and Archaeobotany 11,* 41-54.

Fairbairn A., Near J. & Martinoli D. 2005. Macrobotanical investigations of the North, South, and KOPAL area excavations at Çatalhöyük East. In *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*. (ed.) Hodder I. Cambridge &Ankara: McDonald Institute for Archaeological Research & British Institute at Ankara, 137-202.

Farid S. 2007a. Introduction to the South Areas excavations. In (Ed.) Hodder I. *Excavating Çatalhöyük: South, North and KOPAL area reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 41-58.

Farid S. 2007b. Level IX relative heights, Building 2, Buildings 22 &16 and Building 17. In (Ed.) Hodder I. *Excavating Çatalhöyük: South, North and KOPAL area reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 139-226.

Farid S. 2008. A review of the Mellaart Level system and the introduction of a new phasing system at Çatalhöyük 2008. *Archive report on the Çatalhöyük season 2008.* www.catalhoyuk.com , 15-27. (Retrieved on 10.06.09).

Field A. & Purves D. 1964. The intake of soil by grazing sheep. *Proceedings of the Nutrition Society* 23, xxiv-xxv.

Flanagan L., Comstock J. & Ehleringer J. 1991. Comparison of modelled and observed environmental influences on the stable oxygen and hydrogen isotope composition of leaf water in *Phaseolus vulgaris L. Plant Physiology 96,* 588-596.

Flannery K. 1969. Origins and ecological effects of early domestication in Iran and the Near East: a comparative study. In (Eds.) Ucko P. & Dimbleby G. *The domestication and exploitation of plants and animals.* London: Duckworth, 73-100.

Fontugne M., Kuzucuoğlu C., Karabıyıkoğlu M., Hatte C. & Pastre J-F. 1999. From Pleniglacial to Holocene: a ^{14}C chronostratigraphy of environmental change in the Konya Basin, Turkey. *Quaternary Science Reviews 18,* 573-591.

Forbes H. 1998. European agriculture viewed bottom-side upwards; fodder and foarage provision in a traditional Greek community. In (Eds.) Charles M., Halstead P. & Jones G. *Environmental Archaeology 1. Fodder:Archaeological, historical and ethnographic studies.* Oxford: Oxbow, 19-34.

Fortelius M. & Solounias N. 2000. Functional characterization of ungulate molars using the abrasion-attrition wear gradient: a new method for reconstructing palaeodiets. *American Museum Novitates 3301,* 1-36.

Franz-Odendaal & Kaiser T. 2003. Differential mesowear in the maxillary and mandibular cheek dentition of some ruminants (Artiodactyla). *Annales Zoologici Fennici 40,* 395-410.

French D. 1970. Notes on site distribution in the Çumra area. *Anatolian Studies 20,* 139-148.

French D., Hillman G., Payne S. & Payne R. 1972. Excavations at Can Hasan III, 1969-1970.In (Eds.) Higgs E. *Papers in economic prehistory: studies by members and associates of the British Academy major research project in the early history of agriculture.* Cambridge University Press, Cambridge, 181-190.

Fricke H., Clyde W. & O'Neil J. 1998. Intra-tooth variations in $\delta^{18}O$ (PO_4) of mammalian tooth enamel as a record of seasonal variations in continental climate variables. *Geochimica et Cosmochimica Acta 62,* 1839-1850.

Fricke H. & O'Neil J. 1996. Inter- and intra- tooth variations in the oxygen isotope composition of mammalian tooth enamel phosphate: implications for palaeoclimatological and palaeobiological research. *Palaeogeography, Palaeoclimatology, Palaeoecology 126,* 91-99.

Fricke H. & O'Neil J. 1999. The correlation between $^{16/18}O$ ratios of meteoric water and surface temperature: its use in investigating terrestrial climate change over geological time. *Early and Planetary Science Letters 170*. 181-196.

Friedman I. & O'Neil J. 1977. *Compilation of stable isotope fractionation factors of geochemical interest*. Reston: US Geological Survey, 1-12.

Fuller D., Allaby R. & Stevens C. 2010. Domestication as innovation: the entanglement of techniques, technology and chance in the domestication of cereal crops. *World Archaeology 42,* 13-28.

Galaty J. & Johnson D. 1990. Introduction. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 1-32.

Galbany J., Martínez L., López-Amor H., Espurz V., Hiraldo O., Romero A., de Juan J. & Pérez-Pérez A. 2005. Error rates in buccal-dental microwear quantification using scanning electron microscopy. *Scanning 27,* 23-29.

Galili E., Weinstein-Evron., Hershkovitz I., Gopher A., Kislev M., Lernau O., Kolska-Horwitz L. & Lernau H. 1993. Atlit-Yam: a prehistoric site on the sea floor off the Israeli coast. *Journal of Field Archaeology 20,* 133-157.

Garfinkel Y. 1985. Yiftahel, Pre-Pottery Neolithic layers, 1983-1984. *Israel Exploration Journal 35,* 59-60.

Garrard A. 1984. The selection of South-west Asian animal domesticates. In (Ed.) Clutton-Brock J. & Grigson C. *Animals and archaeology 3. Early herders and their flocks*. Oxford: British Archaeological Reports (International Series) 202, 117–32.

Garrard A., Betts A., Byrd B. & Hunt C. 1987. Prehistoric environments and settlers in the Azraq Basin. *Levant 19,* 5-26.

Garrard A., Colledge S. & Martin L. 1996. The emergence of crop cultivation and caprine herding in the 'marginal zone' of the southern Levant. In (Ed.) Harris D. *The origins and spread of agriculture and pastoralism in Eurasia.* USA: Smithsonian Institute Press, 204-226.

Gat J. 1996. Oxygen and hydrogen isotopes in the hydrological cycle. *Annual Review of Earth and Planetary Science 24,* 225-262.

Gat J. & Carmi I. 1970. Evolution of the isotopic composition of atmospheric water. *Journal of Geophysics Research 75,* 3039-3048.

Gat J. & Gonfiatini R. 1981. Stable isotope hydrology: deuterium and oxygen-18 in the water cycle. *Technical Report Series 210*. Vienna: IAEA.

Gebel H. 2004. There was no centre: the polycentric evolution of the near eastern Neolithic. *Neo-lithics 1,* 28-32.Geddes D. 1983. Neolithic transhumance in the Mediterranean Pyrenees. *World Archaeology 15,* 51-66.

Geerlings E. 2004. The black sheep of Rajasthan. *Seedling (October),* 11-16.

Geist V. 1971. *Mountain sheep: a study in behaviour and evolution.* Chicago: University of Chicago Press.

Geist V. 2000. Descent, adaptation, adjustment: lessons from the Cervidae and other beasts. In (Eds.) Vbra E. & Schaller G. *Antelopes, deer and relatives.* Connecticut: Yale University Press, 180-188.

Gentry A. 2000. The ruminant radiation. In (Eds.) Vbra E. & Schaller G. *Antelopes, deer and relatives.* Connecticut: Yale University Press, 11-25.

Gifford-Gonzalez D. 1991. Bones are not enough: analogues, knowledge, and interpretive strategies in zooarchaeology. *Journal of Anthropological Archaeology 10,* 215-254.

Gintsburger G., Rochon J. & Conesa A. 1990. The French Mediterranean zones: sheep rearing systems and the present and potential role of pasture legumes. In (Eds.) Osman A., Ibrahim M. & Jones M. *The role of legumes in the farming systems of the Mediterranean areas.* Dordrecht: Kluwer Academic Publishers, 179-194.

Gordon K. 1984. The assessment of jaw movement direction from dental microwear. *American Journal of Physical Anthropology 63,* 77-84.

Goudie A. 1986. The human impact on vegetation. In *The human impact on the natural environment*. London: Blackwell, 26-37.

Grant S., Suckling D., Smith H., Torvell L., Forbes T. & Hodgson J. 1985. Comparative studies of diet selection by sheep and cattle: the hill grasslands. *The Journal of Ecology 73,* 987-1004.

Grayzel J. 1990. Markets and migrations: a Fulbe pastoral system in Mali. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 35-68.

Grellier B. 2006. A transhumant shepherd on Mount Aigoual: sheep transhumance and the shepherd's knowledge. *International Social Science Journal 187,* 161-164.

Grine F., Ungar P. & Teaford M. 2002. Error rates in dental microwear quantification using scanning electron microscopy. *Scanning 24*, 144-153.

Gügel A., Grupe G. & Kunzelmann K-H. 2001. Simulation of dental microwear: characteristic traces by opal phytoliths give clues to ancient human dietary behaviour. *American Journal of Physical Anthropology 114*, 124-138.

Guilaine J. & Briois F. 2001. Parekklisha-Shillourokambos. An early Neolithic site in Cyprus. In (Ed.) Swiny S. *The earliest prehistory of Cyprus. From colonization to exploitation*. Boston: American Schools of Oriental Research Archaeological Reports, 37-53.

Hall A. & Kenwood H. 1998. Disentangling dung: pathways to stable manure. *Environmental Archaeology 1,* 123-126.

Halstead P. 1989. The economy has a normal surplus: economic stability and social change among early farming communities of Thessaly, Greece. In (Eds.) Halstead P. & O'Shea J. *Bad year economics: cultural responses to risk and uncertainty*. Cambridge: CUP, 68-80.

Halstead P. 1990. Present to past in the Pindhos: cultural diversification and specialisation in mountain economies. *Rivista di Studi Liguri 1-4,* 61-80.

Halstead P. 1996. Pastoralism or household herding? Problems of scale and specialization in early Greek animal husbandry. *World Archaeology 28,* 20-42.

Halstead P. 1998a. Mortality models and milking: problems of uniformitarianism, optimality and equifinality reconsidered. *Anthropozoologica* 27, 3-20.

Halstead P. 1998b. Ask the fellow who lops the hay: leaf-fodder in the mountains of northwest Greece. *Rural History 9,* 211-234.

Halstead P. 2006. Sheep in the garden: the integration of crop and livestock husbandry in early farming regimes of Greece and Southern Europe. In (Eds.) Serjeantson D. & Field D. *Animals in the Neolithic of Britain and Europe.* Oxford: Oxbow, 42-55.

Halstead P., Collins P. & Isaakidou V. 2002. Sorting the sheep from the goats: morphological distinctions between the mandibles and mandibular teeth of adult *Ovis* and *Capra*. *Journal of Archaeological Science 29,* 545-553.

Halstead P. & O'Shea J. 1989. Introduction: cultural responses to risks and uncertainty. In (Eds.) Halstead P. & O'Shea J. *Bad year economics: cultural response to risk and uncertainty*. Cambridge: Cambridge University Press, 1-7.

Halstead P. & Tierney J. 1998. Leafy hay: an ethnoarchaeological study in NW Greece. In (Eds.) Charles M., Halstead P. & Jones G. *Environmental Archaeology 1. Fodder: Archaeological, historical and ethnographic studies.* Oxford: Oxbow, 71-80.

Hamilton N. 2005a. The figurines. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 187-214.

Hamilton N. 2005b. The beads. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara 325-32.

Hamilton N. 2005c. Social aspects of burial. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 301-306.

Hauptmann H. 1999. The Urfa region. In (Eds.) Özdöğan M. & Başgelen N. *Neolithic in Turkey in the cradle of civilization.* Istanbul: Arkeoloji ve Sanat Yayınları, 65-86.

Healy W. & Ludwig T. 1965. Wear of sheep teeth: the role of ingested soil. *New Zealand Journal of Agricultural Research 8,* 737-752.

Hedges R., Saville A. & O'Connell T. 2008. Characterising the diet of individuals at the Neolithic chambered tomb of Hazelton North, Gloucestershire, England, using stable isotopic analysis. *Archaeometry 50,* 114-128.

Helmer D. 1988. Les animaux de Cafer et des sites Preceramiques dud Sudest de la Turquie: essai de synthese. *Anatolica 15,* 37-48.

Helmer D. 1991. Les changements des strategies de chasse dans le Néolithique Précéramique de Cafer Höyük Est (Turquie). *Cahiers de l'Eupharate 5*, 131-138.

Helmer D. 1992. *La domestication des animaux par les hommes préhistoriques.* Paris: Mason.

Helmer D. 2008. Révision de la faune de Cafer Höyük (Malatya, Turquie): rapports des méthodes de l'analyse des mélanges et de l'analyse de Kernel à la mise en evidence de la domestication. In (Eds.) Vila E., Gourichon L., Choyke A. & Buitenhuis H. *Archaeozoology of the Near East VIII.* Lyon: Maison de l'Orient et de la Méditerrrané, 169-196.

Helmer D. & Gourichon L. 2008. Premières données sur les modalités de subsistance à Tell Aswad (Syrie, PPNB moyen et récent, Néolithique céramique ancien) – Fouilles 2001 – 2005. In (Eds.) Vila E., Gourichon L., Choyke A. & Buitenhuis H. *Archaeozoology of the Near East VIII* . Maison de l'Orient et de la Méditerranée, 119-152.

Helmer D., Gourichon L., Monchot H., Peters J. & Saña M. 2005. Identifying early domestic cattle from Pre-pottery Neolithic sites on the Middle Euphrates using sexual dimorphism. In (Eds.) Vigne J-D., Peters J. & Helmer D. *The first steps of animal domestication.* 9th ICAZ conference, Durham 2002. Oxford: Oxbow, 86-95.

Helmer D., Gourichon L. & Vila E. 2007. The development of the exploitation of products from *Capra* and *Ovis* (meat, milk and fleece) from the PPNB to the Early Bronze Age in the northern Near East (8700-2000 cal. BC). *Anthropozoologica 42*, 4-66.

Hemmer H. 1990. *Domestication: the decline of environmental appreciation*. Cambridge: Cambridge University Press.

Henton E., Meier-Augenstein W. & Kemp H. 2010. The use of oxygen isotopes in sheep molars to investigate past herding practices at the Neolithic settlement of Çatalhöyük, central Anatolia. *Archaeometry 52*, 429-449.

Hesse B. 1978. (Unpublished PhD thesis). *Evidence for husbandry from the Early Neolithic sites of Ganj Dareh in Western Iran.* Ann Arbor: Columbia University.

Hesse B. 1984. These are our goats: the origins of herding in west central Iran. In (Eds.) Clutton-Brock J. & Grigson C. *Animals in archaeology 3: early herders and their flocks.* British Archaeological Reports (International Section) 202, 243-264.

Hiendleder S., Mainz K., Plante Y. & Lewalski H. 1998. Analysis of mitochondrial DNA indicates that domestic sheep are derived from two different ancestral maternal sources: no evidence for contributions from urial and argali sheep. *Journal of Hereditary 89*, 113–120.

Hillman G. 1996. Late Pleistocene changes in wild plant-foods available to hunter–gatherers of the northern Fertile Crescent: possible preludes to cereal cultivation. In (Ed.) Harris D. *The origins and spread of agriculture and pastoralism in Eurasia.* Washington D.C.: Smithsonian Institution Press, 159-203.

Hillman G., Hedges R., Moore A., Colledge S. & Pettitt P. 2001. New evidence of late glacial cereal cultivation at Abu Hureyra on the Euphrates. *The Holocene 11, 383-393.*

Hillson S. 2005 (2nd Edition). *Teeth*. Cambridge; Cambridge University Press.

Hodder I. 1990. *The domestication of Europe.* Oxford: Blackwell.

Hodder I. 1996. *On the surface: Çatalhöyük 1993 -95.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Hodder I. 2000. *Towards reflexive method in archaeology: the example at Çatalhöyük.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Hodder I. 2005a. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Hodder I. 2005b. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Hodder I. 2005c. *Çatalhöyük perspectives: themes from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Hodder I. 2006. *The leopard's tale*. London: Thames & Hudson.

Hodder I. 2007. *Excavating Çatalhöyük: South, North and KOPAL area reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Hodder I. & Cessford C. 2004. Daily practice and social memory at Çatalhöyük. *American Antiquity 69,* 17-40.

Hodder I., Cessford C. & Farid S. 2007. Introduction to methods and approaches. In (Ed.) Hodder I. *Excavating Çatalhöyük: South, North and KOPAL area reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 3-24.

Hodgson J., Forbes T., Armstrong R., Beattie M. & Hunter E. 1991. Comparative studies of the ingestive behaviour and herbage intake of sheep and cattle grazing indigenous hill plant communities. *Journal of Applied Ecology 28,* 205-227.

Hofmann R. 1989. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia 78*, 443-457.

Hole F. 1978. Pastoral nomadism in Western Iran. In (Ed.) Gould R. *Explorations in ethnoarchaeology*. Albuquerque : University of Mexico Press, 127.168.

Hole F., Flannery K. & Neely J. 1969. *Prehistory and human ecology of the Deh Luran plain: an early village sequence from Khuzistan, Iran*. Memoir 1, Museum of Anthropology, University of Michigan.

Hongo H. & Meadow R. 1998. Pig exploitation at Neolithic Çayönü Tepesi (Southeastern Anatolia). In (Ed.) Nelson S. *Ancestors for pigs: pigs in prehistory*. MASCA Research Papers in Science and Archaeology 15, 77-98.

Hongo H., Pearson J., Öksüz B. & İlgezedi G. 2009. The process of ungulate domestication at Çayönü, Southeastern Turkey: a multidisciplinary approach focusing on *Bos* sp. and *Cervus elaphus*. *Anthropozoologica 44*, 63-78.

le Houérou H. 1977. Plant sociology and ecology applied to grazing lands research, survey, and management in the Mediterranean Basin. In (Ed.) Krause W. *Application of vegetation science to grassland husbandry*. The Hague: Dr. W. Junk, 213-276.

le Houérou H. 1981. Impact of man and his animals on Mediterranean vegetation. In (Eds.) Castri F., Goodall D. & Specht R. *Mediterranean-type shrublands*. Amsterdam: Elsevier Scientific Publishing Company, 479-522.

Horwitz L. 1988. Fauna from the PPNB site of Yiftahel: new perspectives on domestication. *Mitekufat Haeven 20*, 181-182.

Horwitz L. 1989. A reassessment of caprovine domestication in the Levantine Neolithic: old questions, new answers. In (Ed.) Hershkovitz I. *People and culture change: proceedings of the second symposium on Upper Palaeolithic, Mesolithic and Neolithic populations of Europe and the Mediterranean basin*. British Archaeological Reports (International Series) 508, 153–180.

Horwitz L. & Smith P. 1990. A radiographic study of the extent of variation in cortical bone thickness in soay sheep. *Journal of Archaeological Science 17*, 655-664.

Hunn E. 1982. The utilitarian factor in folk biological classification. *American Anthropologist 84*, 830-847.

Hurtchinson K. & King K. 1980. Management impacts on structure and function of sown grasslands. In (Eds.) Breymeyer A. & van Dyne G. *Grasslands, systems analysis and man*. Cambridge: CUP, 823-852.

Iacumin P., Bocherans H., Mariotti A. & Longinelli A. 1996. Oxygen isotope analysis of co-existing carbonate and phosphate in biogenic apatite: a way to monitor diagenetic alteration of bone phosphate? *Earth and Planetary Science Letters 1*, 1-6.

Iacumin P. & Longinelli A. 2002. Relationship between $\delta^{18}O$ values for skeletal apatite from reindeer and foxes and yearly mean $\delta^{18}O$ values of environmental water. *Earth and Planetary Science Letters 201*, 213-219.

IAEA. 2001. *GNIP maps and animation.* International Atomic Energy Agency, Vienna. *isohis.iaea.org.* (Retrieved on 15.12. 09).

IAEA/WMO. 2006. Global network of isotopes in precipitation. *The GNIP database*. isohis.iaea.org. (Retrieved on 15.12. 09).

Ilgezdi G. 2000. Zooarchaeology at Çayönü: a preliminary assessment of the red deer bones. In (Eds) Mashkour M., Choyke A., Buitenhuis H. & Poplin F. *Archaeozoology of the Near East IV: proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas.* Groningen: ARC Publications, 141-153.

Ingold T. 1993. The temporality of the landscape. *World Archaeology 25,* 152-175.

Ingold T. 1994. From trust to domination: an alternative history of human-animal relations. In (Eds.) Manning A. & Serpell J. *Animals and human society: changing perspectives.* London: Routledge, 1-22.

Ingold T. 1996. Growing plants and raising animals: an anthropological perspective on domestication. In (Ed.) Harris D. *The origins and spread of agriculture and pastoralism in Eurasia*. USA: Smithsonian Institution Press, 12–24.

Janis C. 1990. The correlation between diet and dental wear in herbivorous mammals, and its relationship to the determination of diets of extinct species. In (Ed.) Boucot A. *Evolutionary palaeobiology of behaviour and coevolution*. Oxford: Elsivier, 241-259.

Janis C., Damuth J. & Theodor J. 2002. The origins and evolution of the North American grassland biome: the story from the hoofed mammals. *Palaeogeography, Palaeoclimatology, Palaeoecology 177,* 183-198.

Janis C., Damuth J. & Theodor J. 2004. The species richness of Miocene browsers, and implications for habitat type and primary productivity in the North American grassland biome. *Palaeogeography, Palaeoclimatology, Palaeoecology 207,* 371-398.

Janssen B. 1972. The significance of the fallow year in the dry-farming system of the Great Konya Basin, Turkey. *Netherlands Journal of Agricultural Science 20,* 247-260.

Jenkins E. 2005. Çatalhöyük microfauna: preliminary results and interpretation. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 111-116.

Jenkins E. 2009a. *Unwanted inhabitants? the microfauna from Çatalhöyük and Pınarbaşı*. Saarbrücken, Germany: VDM-Verlag.

Jenkins E. 2009b. Phytolith taphonomy: a comparison of dry ashing and acid extraction on the breakdown of conjoined phytoliths formed in *Triticum durum. Journal of Archaeological Science 36,* 2402–2407.

Jones G., Bogaaard A., Charles M. & Hodgson J. 2000. Distinguishing the effects of agricultural practices relating to fertility and disturbance: a functional ecological approach in archaeobotany. *Journal of Archaeological Science 27,* 1073-1084.

Jones M. & Roberts N. 2008. Interpreting lake isotope records of Holocene environmental change in the eastern Mediterranean. *Quaternary International 181,* 32-38.

Jones M., Roberts N. & Leng M. 2007. Quantifying climatic change through the last glacial- interglacial transition based on lake isotope palaeohydrology from central Turkey. *Quaternary Research 67,* 463-473.

Joukowsky M. 1996. The Neolithic. In (Ed.) Joukowsky M. *Early Turkey: an introduction to the archaeology of Anatolia from Prehistory through the Lydian period*. Iowa: Kendall Hunt Publications, 67-113.

Kaufman P., Dayanandan P. & Franklin C. 1985. Structure and function of silica bodies in the epidermal system of grass shoots. *Annals of Botany 55,* 487-507.

Kaya M. & Aksoylar M. 1992. Bozdağ (Konya)'da yaşayan Anadolu yaban koyunu, *Ovis orientalis anatolica* Valenciennes 1856'nin davranışları. *Doğa Türkiye Journal of Zoology 16*, 229-241.

Kaya M., Bunch T. & Konuk M. 2004. On Konya wild sheep *Ovis orientalis anatolica* in the Bozdağ protected area. *Mammalia 68,* 229-232.

Kenyon K. 1957. *Digging up Jericho*. London: Benn.

Keswani P. 1994. The social context of animal husbandry in early agricultural societies: ethnographic insights and an archaeological example from Cyprus. *Journal of Anthropological Archaeology 13,* 255-277.

Khalaily H., Marder O. & Milevski I. 2000. New excavations at the PPNB site of Yiftahel, Israel. *Neo-Lithics 2,* 18-20.

Klein R. & Cruz-Uribe K. 1984. *The analysis of animal bones from archaeological sites.* Chicago: University of Chicago Press.

Klein R., Wolf C., Freeman L. & Allwarden K. 1981. The use of dental crown heights for constructing age profiles of red deer and similar species in archaeological samples. *Journal of Archaeological Science* 8, 1-31.

Köhler-Rollefson I. 1988. The aftermath of the Levantine Neolithic revolution in the light of ecological and ethnographic evidence. *Paléorient 14,* 87-93.

Köhler-Rollefson I. 1989. Changes in goat exploitation at 'Ain Ghazal between the early and late Neolithic: a metrical analysis. *Paléorient 15,* 141-146.

Köhler-Rollefson I. 1992. A model for the development of nomadic pastoralism on the Transjordanian Plateau. In (Eds.) Bar-Yosef O. & Khazanov A. *Pastoralism in the Levant.* Madison: Prehistory Press, 11-18.

Köhler-Rollefson I. & Rollefson G. 1990. The impact of Neolithic subsistence strategies on the environment: the case of 'Ain Ghazal, Jordan. In (Eds.) Bottema S., Entjes-Nieborg N. & van Zeist W. *Man's role in the shaping of the eastern Mediterranean landscape*. Rotterdam: Balkema, 3-13.

Kohn M., Schoeninger M. & Valley J. 1998. Variability in oxygen isotope compositions of herbivore teeth: reflections of seasonality or developmental physiology? *Chemical Geology 152,* 97-112.

Kolodny Y., Luz B. & Navon O. 1983. Oxygen isotope variations in phosphate of biogenic apatites, I. fish bone apatite – rechecking the rules of the game. *Earth and Planetary Science Letters 64,* 398-404.

Kramer C. 1982. *Village ethnoarchaeology: rural Iran in archaeological perspective.* New York: Academic Press.

Kuijt I. (Ed.). 2000. *Life in Neolithic farming communities; social organisation, identity and differentiation.* New York: Kluwer Academic.

Kuzucuoğlu C. 2002. The environmental frame in Central Anatolia from the 9th to 6th millennia cal. BC. An introduction to the study of relations between environmental conditions and the development of human societies. In (Eds.) Gérard F. & Thissen L. *The Neolithic of Central Anatolia: Central Anatolia Neolithic e-Workshop (CANeW) table ronde.* Istanbul: Ege Yayınları, 33-58.

Lancaster W. & Lancaster F. 1991. Limitations on sheep and goat herding in the eastern Badia of Jordan: and ethno-archaeological enquiry. *Levant 23,* 125-13.

Landau S., Perevolotsky A., Bonfil D., Barkai D.& Silanikove N. 2000. Utilization of low quality resources by small ruminants in Mediterranean agro-pastoral systems: the case of browse and aftermath cereal stubble. *Livestock Production Science 64,* 39-49.

Last J. 1996. Surface pottery at Çatalhöyük. In (Ed.) Hodder I. *On the surface: Çatalhöyük 1993 -95.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 115-172.

Last J. 1999. Pottery. *Çatalhöyük 1999 Archive Report.* www.catalhoyuk.com. (Retrieved on 15.07.09).

Last J. 2005a. Pottery from the East Mound. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 101-138.

Last J. 2005b. Art. In (Ed.) Hodder I. *Çatalhöyük perspectives: themes from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 197-208.

Lawrence B. 1980. Evidences of animal domestication at Çayönü. In (Eds.) Çambel H., Braidwood R. & Benedict P. *İstanbul ve Chicago Üniversiteleri karma projesi güneydoğu Anadolu tarihöncesi araştırmaları.* The Joint Istanbul-Chicago Universities' prehistoric research in southeastern Anatolia. Istanbul:Edebiyet Fakültesi Basımevi, 285-308.

Lawrence B. 1982. Principle food animals at Çayönü. In (Eds.) Braidwood L. & Braidwood R. *Prehistoric village archaeology in south east Turkey*. Oxford: British Archaeological Reports (International Series) 138, 175-199.

LeBrun A. 1994. *Fouilles récentes à Khirokitia (Chypre), 1988-1991*. Paris: Éditions Recherche sur les civilisations.

Lee-Thorp J. 2002. Two decades of progress towards understanding fossilization processes and isotopic signals in calcified tissue minerals. *Archaeometry 44*, 435-446.

Lee-Thorp J. 2008. On isotopes and old bones. *Archaeometry 50*, 925-950.

Legge A. 1996. The beginning of caprine domestication in southwest Asia. In (Ed.) Harris D. *The origins and spread of agriculture and pastoralism in Eurasia.* Washington: Smithsonian Institute, 238-262.

Legge A. & Rowley-Conwy P. 2000. The exploitation of animals. In (Eds.) Moore A. Hillman G. & Legge A. *Village on the Euphrates–from foraging to farming at Abu Hureyra.* Oxford: Oxford University Press, 455-471.

Lenarz M. 1979. Social structure and reproductive strategy in desert bighorn sheep (*Ovis Canadensis mexicana*) *Journal of Mammology 60*, 671-678.

Leng M. (Ed.) 2006. *Isotopes in palaeoenvironmental research.* TheNetherlands:Springer.

Leng M., Roberts N., Reed J. & Sloane H. 1999. Late Quaternary palaeohyrdrology of the Konya Basin, Turkey, based on isotope studies of modern hydrology and lacustrine carbonates. *Journal of Paleolimnology 22*, 187-204.

Lieberman D. 1993. Life history variables preserved in dental cementum microstructure. *Science 261*, 1162-1164.

Little M. & Leslie P. 1999. *Turkana herders of the dry savanna*. Oxford: Oxford University Press.

Longinelli A. 1984. Oxygen isotopes in mammal bone phosphate: a new tool for paleohydrological and palaeoclimatological research? *Geochimica et Cosmochimica Acta 48*, 385-390.

Lösch S., Grupe G. & Peters J. 2005. Stable isotopes and dietary adaptations in humans and animals at Pre-Pottery Neolithic Nevalı Çori, south-east Anatolia. *American Journal of Physical Anthropology 131*, 181-193.

Love S. 2010. (Unpublished PhD thesis). *Building mudbrick communities through Neolithic architecture*. Anthropology Department: Stanford University, USA.

Luz B., Cormie A. & Schwarcz H. 1990. Oxygen isotope variations in phosphate of deer bones. *Geochimica et Cosmochimica Acta 54*, 1723-1728.

Luz B. & Kolodny Y. 1985. Oxygen isotope variations in phosphate of biogenic apatites, IV. Mammal teeth and bones. *Earth and Planetary Science Letters 75*, 29-36.

Lyman R. 1994. *Vertebrate Taphonomy*. Cambridge: Cambridge University Press.

Lynch A., Hamilton J. & Hedges R. 2008. Where the wild things are: aurochs and cattle in England. *Antiquity 82*, 1025-1039.

McCorriston J. 1992. (Unpublished PhD thesis). *The early development of agriculture in the ancient near east: an ecological and evolutionary study*. Yale University, Connecticut.

Maas M. 1991. Enamel structure and microwear: an experimental study of the response of enamel to shearing forces. *American Journal of Physical Anthropology 85*, 31-50.

Mainland I. 1998a. The lamb's last supper: the role of dental microwear analysis in reconstruction of livestock diet in the past. *Environmental Archaeology 1*, 55-62.

Mainland I. 1998b. Dental microwear and diet in domestic sheep *(Ovis aries*) and goats (*Capra hircus*): distinguishing grazing and fodder-fed ovicaprids using a quantitative analytical approach. *Journal of Archaeological Science 25*, 1259-1271.

Mainland I. 2000. A dental microwear study of seaweed-eating and grazing sheep from Orkney. *International Journal of Osteoarchaeology 10*, 93-107.

Mainland I. 2001. The potential of dental microwear for exploring seasonal aspects of sheep husbandry and management in Norse Greenland. *Archaeozoologia 11*, 79-100.

Mainland I. 2003. Dental microwear in grazing and browsing Gotland sheep (*Ovis aries*) and its implications for dietary reconstruction. *Journal of Archaeological Science 30*, 1513-1527.

Mainland I. 2006. Pastures lost? A dental microwear study of ovicaprine diet and management in Norse Greenland. *Journal of Archaeological Science 33*, 238-252.

Mainland I. & Halstead P. 2002. The diet and management of domestic sheep and goats at Neolithic Makriyalos. In (Eds.) Davis J., Fabis M., Mainland I., Thomas R. & Richards M. *Health and diet in past animals populations*. Oxford: Oxbow, 104-112.

Makarewicz, C. & Tuross N. 2006. Foddering by Mongolian pastoralists is recorded in the stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes of caprine dentinal collagen. *Journal of Archaeological Science 33*, 862-870.

Maltby J. 1985. Patterns in faunal assemblage variability. In (Eds.) Barker G. & Gamble C. *Beyond domestication in Prehistoric Europe*. New York: Academic Press, 33-74.

Marciniak A. 2005. *Placing animals in the Neolithic.* London: UCL Press.

Marciniak A. 2007. Digging a nation beside a nation. The case of Çatalhöyük, Anatolia, Turkey. In (Eds.) Ucko P., Ling Q. & Hubert J. *From concept of the past to practical strategies.* London: Saffron Books, 281 -302.

Martin L. 1999. Mammal remains from the eastern Jordanian Neolithic, and the nature of caprine herding in the steppe. *Paléorient 25*, 87-104.

Martin L., Russell N. & Carruthers D. 2002. Animal remains from the Central Anatolian Neolithic. In (Eds.) Thissen L. & Gérard F. *The Neolithic of Central Anatolia: internal developments and external relations during the 9th-6th millennia cal. BC.* Proceedings of the International Central Anatolia Neolithic e-Workshop (CANeW) table ronde. Istanbul: Ege Yayınları, 193-216.

Mashkour M., Bocherens H. & Moussa I. 2002. Long distance movements of sheep and goats of Bakhtiari nomads tracked with intra-tooth variations of stable isotopes (^{13}C and ^{18}O). In (Eds.) Davies J. & Fabis M. *9th ICAZ conference. Diet and health in past animal populations*, 113-124.

Matthews W. 2005. Micromorphological and microstratigraphic traces of uses and concepts of space. In (Ed.) Hodder I. *Inhabiting Çatalhöyük*. Ankara: British Institute of Archaeology at Ankara. Cambridge: McDonald's Institute for Archaeological Research, 395-398.

Matthews W., French C., Lawrence T., Cutler D. & Jones M. 1997. Microstratigraphic traces of site formation processes and human activities. *World Archaeology 29*, 281-308.

Matthews W., Hastorf C. & Ergenekon B. 2000. Ethnoarchaeology: studies in local villages aimed at understanding aspects of the Neolithic site. In (Ed.) Hodder I. *Towards reflexive methods in archaeology: the example of Çatalhöyük.* Cambridge: McDonald's Institute for Archaeological Research, 177-188.

Matthews W., Wiles J. & Almond M. 2006. Micromorphology. *Çatalhöyük 2006 archive report.* www.catalhoyuk.com, 285-294. (Retrieved on 14.07.09).

Meadow R. 1989. Osteological evidence for the process of animal domestication. In (Ed.) Clutton-Brock J. *The walking larder.* London: Unwin Hyman, 80-90.

Meadow R. 1992. Inconclusive remarks on pastoralism, nomadism, and other animal-related matters. In (Eds.) Bar-Yosef O. & Khazanov A. *Pastoralism in the Levant*. Madison: Prehistory Press, 261-268.

Meadows J., Cemal I. & Karaca O., Gootwine E. & Kijas J. 2007. Five ovine mitochondrial lineages identified from sheep breeds of the near East. *Genetics 175*, 1371-1379.

Meier-Augenstein W. 2007. Stable isotope fingerprinting – chemical element 'DNA'? In (Eds.) Thompson T. & Black S. *Forensic Human Identification*. Boca Raton, Florida: CRC Press, 29-53.

Meiggs D. 2007. Visualizing the seasonal round: a theoretical experiment with strontium isotope profiles in ovicaprine teeth. *Anthropozoologica 42*, 107-127.

Mellaart J. 1962. Excavations at Çatal Hüyük, first preliminary report, 1961. *Anatolian Studies 12,* 41-65.

Mellaart J. 1963. Excavations at Çatal Hüyük, second preliminary report, 1962. *Anatolian Studies 13,* 43-103.

Mellaart J. 1964. Excavations at Çatal Hüyük, third preliminary report, 1963. *Anatolian Studies 14,* 39-119.

Mellaart J. 1966. Excavations at Çatal Hüyük, fourth preliminary report, 1965. *Anatolian Studies 16,* 15-191.

Mellaart J. 1967. *Çatal Hüyük; a Neolithic town in Anatolia*. London: Thames and Hudson.

Merceron G., Blondel C., Brunet M., Sen S., Solounias N., Viriot L. & Heintz E. 2004b. The Late Miocene palaeoenvironment of Afghanistan as inferred from dental microwear in artiodactyls. *Palaeogeography, Palaeoclimatology, Palaeoecology 207,* 143-163.

Merceron G., de Bonis L., Viriot L. & Blondel C. 2005. Dental microwear of fossil bovids from northern Greece: paleoenvironmental conditions in the eastern Mediterranean during the Messinian. *Palaeogeography, Palaeoclimatology, Palaeoecology 217,* 173-185.

Merceron G., Viriot L. & Blondel C. 2004a. Tooth microwear patterns in roe deer (*Capreolus capreolus* L.) from Chizé (Western France) and relation to food consumption. *Small Ruminant Research 53,* 125-132.

Merceron G., Zazzo A., Spassov N., Geraads D. & Kovachev D. 2006. Bovid paleolecology and paleoenvironments from the late Miocene of Bulgaria: evidence from dental microwear and stable isotopes. *Palaeogeography, Paleoclimatology, Palaeoecology 241,* 637-654.

Meskell L. 2007. Refiguring the corpus at Çatalhöyük. In (Eds.) Renfrew C. & Morley I. *Material beginnings: a global prehistory of figurative representation*. Cambridge: McDonald Institute Monographs, 143-156.

Meskell L. 1999. *Archaeologies of social life; age, sex, class et cetera in ancient Egypt.* Oxford: Blackwell.

Meskell L. 2008. The nature of the beast: curating animals and ancestors at Çatalhöyük. *World Archaeology 40,* 373-389.

Meskell L., Nakamura C., King R. & Farid S. 2008. Figured lifeworlds and depositional practices at Çatalhöyük. *Cambridge Archaeological Journal 18,* 139-161.

Milhaud G. & Nezit J. 1991. Développment des molaires chez le mouton. *Recueil de Mèdecine Vètèrinaire 167,* 121-127.

Miller N. & Smart T. 1984. Intentional burning of dung as fuel: a mechanism for the incorporation of charred seeds into the archaeological record. *Journal of Ethnobiology 4,* 15-28.

Molleson T., Andrews P. & Boz B. 2005. Reconstruction of the Neolithic people of Çatalhöyük. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 279–300.

Monahan B. 2000. (Unpublished PhD thesis). *The organisation of domestication at Gritille, a Pre-pottery Neolithic B site in Southeastern Turkey.* Department of Anthropology, Northwestern University.

Moore A., Hillman G. & Legge A. 2000. *Village on the Euphrates.* Oxford: Oxford University Press.

Moran N. & O'Connor T. 1994. Age attribution in domestic sheep by skeletal and dental maturation; a pilot study of available resources. *International Journal of Osteoarchaeology 4,* 267-286.

Moreno D. & Raggio O. 1990. The making and fall of an intensive pastoral land-use system. Eastern Liguria, 16-19th centuries. *Rivista di Studi Liguri 1-4,* 193-217.

le Mort F., Vigne J-D., Davis S., Guilaine J. & Le Brun A. 2008. Man-animal relationships in the Pre-Pottery burials at Shillourokambos and Khirokitia (Cyprus, 8th and 7th millennia cal. BC). In (Eds.) Vila E., Gourichon L., Choyke A. & Buitenhuis H. *Archaeozoology of the Near East VIII.* Lyon: Maison de l'Orient et de la Méditerrrané, 119-241.

Mortensen P. 1972. Seasonal camps and early villages in the Zagros. In (Eds.) Ucko P., Tringham R. & Dimbleby G. *Man, settlement and urbanism.* London: Duckworth, 293-297.

Moss-Salentijn L., Moss M. & Sheng-Tien Yuan M. 1997. The ontogeny of mammalian enamel. In (Eds.) van Koenigswald W. & Sander P. *Tooth enamel microstructure.* Rotterdam: Balkema.

Muller M. 1982. *Tasks for vegetation science. No 5. Selected climatic data for a global set of standard stations for vegetation science.* London: Junk.

Muller W., Fricke H., Halliday A., McCullock M. & Wartho J. 2003. Origin and migration of the Alpine iceman. *Science 302,* 862-866.

Munson P. 2000. Age-correlated differential destruction of bones and its effect on archaeological mortality profiles of domestic sheep and goats. *Journal of Archaeological Science 27,* 391-407.

Nahal I. 1981. The Mediterranean climate from a biological viewpoint. In (Eds.) de Castri F., Goodall D. & Specht R. *Mediterranean-type shrublands.* Amsterdam: Elsevier Scientific Publishing Company, 63-86.

Nandris J. 1990. The Balkan dimension of highland zone in pastoralism. *Rivista di Studi Liguri 1.4,* 99-107.

Naveh Z. 1990. Ancient man's impact on the Mediterranean landscape in Israel – ecological and evolutionary perspectives. In (Eds.) Bottema S., Entjes-Nieborg N. & van Zeist W. *Man's role in the shaping of the eastern Mediterranean landscape.* Rotterdam: Balkema, 43-50.

Nissen H. 1993. The PPNC, the sheep and the '*Hiatus Palestinien*'. *Paléorient 19,* 177-182.

Nyerges E. 1980. Traditional pastoralism. *Expedition 22,* 36-41.

Nystrom P., Phillips-Conroy J. & Jolly C. 2004. Dental microwear in anubis and hybrid baboons (*Papio hamadryas, sensu lato*) living in Awash National Park, Ethiopia. *American Journal of Physical Anthropology* 125, 279-291.

O'Connell T. & Hedges R. 1999. Investigations into the effect of diet on modern human hair isotopic values. *American Journal of Physical Anthropology 108,* 409-425.

O'Connor T. 1998. On the difficulty of detecting seasonal slaughtering of sheep. *Environmental Archaeology 3,* 5-11.

Öksüz B. 2000. Analysis of the cattle bones of the Pre-pottery Neolithic settlement of Çayönü. In (Eds.) Mashkour M., Choyke A., Buitenhuis H. & Poplin F. *Archaeozoology of the Near East IV: proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas.* Groningen: ARC Publications, 154-163.

Orton D. 2008. (Unpublished PhD thesis). *Beyond hunting and herding: humans, animals and the political economy of the Vinča period.* Faculty of Archaeology and Anthropology, University of Cambridge.

Özbaşaran M. & Buitenhuis H. 2002. Proposal for a regional terminology for Central Anatolia In (Eds.) Thissen L. & Gérard F. *The Neolithic of Central Anatolia: internal developments and external relations during the 9th-6th millennia cal. BC.* Proceedings of the International Central Anatolia Neolithic e-Workshop (CANeW) table ronde. Istanbul: Ege Yayınları, 67-78.

Özbaşaran M., Duru G., Kayacan N., Erdoğu B. & Buitenhuis H. In press, submitted 2007. Musular 1996-2004: a general assessment. In (Eds.) Özdogan M. & Başgelen N. *Neolithic in Turkey.* Istanbul: Arkeoloji ve Sanat Yayınları.

Özdoğan A. 1999. Çayönü. In (Eds.) Özdöğan M. & Başgelen N. *Neolithic in Turkey in the cradle of civilization.* Istanbul: Arkeoloji ve Sanat Yayınları, 35-63.

Özdogan M. 1977. *Aşağı fırat havzası 1977 yüzey araştırması.* Orta Doğu Teknik Üniversitesi aşağı fırat projesi yayınları, Seri: 1, No: 2. Istanbul: Tekofset Basımevi.

Özdoğan M. 1998. Anatolia from the last glacial maximum to the Holocene climatic optimum: cultural formations and the impact of the environmental setting. *Paléorient 23,* 25-38.

Palmer C. 1998. Following the plough: the agricultural environment of Northern Jordan. *Levant 30,* 129-165.

Papachristou T. 1997. Foraging behaviour of goats and sheep on Mediterranean kermes oak shrublands. *Small Ruminant Research 24,* 85-93.

Pawlowskia K. 2007. Microscopic study of bone structure: preliminary report. *Çatalhöyük 2007 archive report*. www.catalhoyuk.com, 164. (Retrieved on 31.07.10).

Payne S. 1969. A metrical distinction between sheep and goat metacarpals. In (Eds.) Ucko P. & Dimbleby G. *The domestication and exploitation of plants and animals.* London: Duckworth, 295-305.

Payne S. 1972. Can Hasan III, the Anatolian Aceramic, and the Greek Neolithic. In (Ed.) Higgs E. *Papers in economic prehistory: studies by members and associates of the British Academy Major Research Project in the Early History of Agriculture.* Cambridge: Cambridge University Press, 191-211.

Payne S. 1973. Kill-off patterns in sheep and goats: the mandibles from Aşvan Kale. *Anatolian Studies 23,* 281-303.

Payne S. 1985. Morphological distinctions between the mandibular teeth of young sheep, *Ovis*, and goats, *Capra. Journal of Archaeological Science 12,* 139-47.

Pearson J. 2010 (Manuscript). Human and animal diets as evidenced by stable carbon and nitrogen isotope analysis.

Pearson J., Buitenhuis H., Hedges R., Martin L., Russell N. & Twiss K. 2007. New light on early caprine herding strategies from isotope analysis: a case study from Neolithic Anatolia. *Journal of Archaeological Science 34,* 2170-2179.

Peltenberg E. (Ed.). 2003. *The colonisation and settlement of Cyprus: investigations at Kissonerga-Mylouthkia, 1976-1996.* Sävedalen: Åström.

Pérez-Pérez A., Galbany J. & Fontarnau R. 2001. Feature extinction in back-scattered S.E.M. analysis. *Biology of the Cell 93,* 438-439.

Perkins D. 1969. Fauna of Catal Huyuk: evidence for early cattle domestication in Anatolia. *Science 164,* 177-179.

Perkins D. & Daly P. 1968. A hunters' village in Neolithic Turkey. *Scientific American 219,* 96-106.

Peters J., Helmer D., von den Driesch A. & Saňa Seguí M. 1999. Early animal husbandry in the northern Levant. *Paléorient 25,* 27-47.

Peters J., von den Driesch A. & Helmer D. 2005. The upper Euphrates-Tigris basin: cradle of agro-pastoralism? In (Eds.) Vigne J-D., Peters J. & Helmer D. *The first steps of animal domestication.* 9th ICAZ conference, Durham 2002. Oxford: Oxbow, 96-124.

Pierotti R. & Wildcat D. 2000. Traditional ecological knowledge: the third alternative (commentary). *Ecological Applications 10,* 1333-1340.

Poage M. & Chamberlain C. 2001. Empirical relationships between elevation and the stable isotope composition of precipitation and surface waters: considerations for studies of palaeoelevation change. *American Journal of Science 301,* 1-15.

Pollard T., Shell C. & Twigg D. 1996. Topographic survey of the Çatalhöyük mounds. In (Ed.) Hodder I. *On the surface: Çatalhöyük 1993-95.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 59-72.

van Poollen H. & Lacey J. 1979. Herbage response to grazing systems and stocking intensities. *Journal of Range Management 32,* 250-253.

Price T., Burton J. & Bentley R. 2002. The characterization of biologically available strontium isotope ratios for the study of Prehistoric migration. *Archaeometry 44,* 117-135.

Pross J., Kotthoff U., Müller U., Peyron O., Dormoy I., Schmiedl G., Kalaitzidis S. & Smith A. 2009. Massive perturbation in terrestrial ecosystems of the eastern Mediterranean region associated with the 8.2kyr B.P. climatic event. *Geology 37,* 887-890.

Puech P-F., Prone A. & H Albertini. 1981. Reproduction expérimentale des processus d'altération de la surface dentaire par friction non abrasive et non adhesive. *Compte Rendu Academie Science Paris 293,* 729-734.

Raish C. 1992. *Domestic animals and stability in pre-state farming societies*. Oxford:British Archaeological Reports(International Series) 579.

Rasmussen P. 1989. Leaf-foddering of livestock in the Neolithic: archaeobotanical evidence from Weier, Switzerland. *Journal of Danish Archaeology 8,* 51-71.

Redding R. 1981 (Unpublished PhD thesis). *Decision making in subsistence herding of sheep and goats in the Middle East.* Michigan: Ann Arbor.

Redding R. 1984. Theoretical determinants of a herder's decisions: modelling variation in the sheep/goat ratio. In (Eds.) Clutton-Brock J. & Grigson C. *Animals and archaeology 3: early herders and their flocks,* 223-241.

Reese D. 2005. The Çatalhöyük shells. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 123-128.

Reimer P., Baillie M., Bard E., Bayliss A., Beck J., Bertrand C., Blackwell P., Buck C., Burr G. Cutler K., Damon P., Edwards R., Fairbanks R., Friedrich M., Guilderson T., Hogg A., Hughen K., Kromer B., McCormac G., Manning S., Ramsey C., Reimer R., Remmele S., Southon J., Stuiver M., Talamo S., Taylor F., van der Plicht J.& Weyhenmeyer C. 2004. Intcal04 terrestrial radiocarbon age calibration, 0-26 kyr BP. *Radiocarbon 46,* 1029-1058.

Reinhard K. & Danielson D. 2005. Pervasiveness of phytoliths in prehistoric southwestern diet and implications for regional and temporal trends for dental microwear. *Journal of Archaeological Science 32,* 981-988.

Richards M., Pearson J., Molleson T., Russell N. & Martin L. 2003. Stable isotope evidence of diet at Neolithic Çatalhöyük, Turkey. *Journal of Archaeological Sciences 30*, 67-76.

Rindsberger M., Magaritz M., Carmi I. & Gilad D. 1983. The relation between air mass trajectories and the water isotope composition of rain in the Mediterranean Sea area. *Geophysical Research Letters 10,* 43-46.

Rivals F. & Deniaux B. 2003. Dental microwear analysis for investigating the diet of an argali population (*Ovis ammon antiqua)* of mid-Pleistocene age, Caune de l'Argo cave, eastern Pyrenees, France. *Palaeogeography, Palaeoclimatology, Palaeoecology 193,* 443-455.

Rivals F. & Deniaux B. 2005. Investigation of human hunting seasonality through dental microwear analysis of two Caprinae in late Pleistocene localities in Southern France. *Journal of Archaeological Science 32,* 1603-1612.

Rivals F., Moncel M-H. & Patou-Mathis M. 2009. Seasonality and intra-site variation of Neanderthal occupations in the Middle Palaeolithic locality of Payre (Ardèche, France) using dental wear analyses. *Journal of Archaeological Science 36*, 1070-1078.

Rivals F. & Semprebon G. 2006. A comparison of the dietary habits of a large sample of the Pleistocene pronghorn *Stockoceros onusrosagris* from the Papago Springs Cave in Arizona to the modern *Antilocapra Americana*. *Journal of Vertebrate Paleontology 26,* 495-500.

Roberts N. 1982. A note on the geomorphological environment of Çatalhöyük. *Journal of Archaeological Science 9*, 341-348.

Roberts N. 1983. Age, palaeoenvironments, and climatic significance of Late Pleistocene Konya Lake, Turkey. *Quaternary Research 19,* 154-171.

Roberts N. 1991. Late Quaternary geomorophological change and the origins of agriculture in south central Turkey. *Geoarchaeology 6,* 1-26.

Roberts N. 2002. Did prehistoric landscape management retard the post-glacial spread of woodland in Southwest Asia? *Antiquity 76,* 1002-1010.

Roberts N., Black S., Boyer P., Eastwood W., Griffiths H., Lamb H. F., Leng M.., Parish R., Reed J., Twigg D., & Yıgıtbaşıoğlu H. 1999. Chronology and stratigraphy of Late Quaternary sediments in the Konya Basin, Turkey: Results from the KOPAL Project. *Quaternary Science Reviews* 18, 611-30.

Roberts N., Boyer P. & R. Parish. 1996. Preliminary results of geoarcheological investigations at Çatalhöyük. In (Ed.) Hodder I. *On the Surface: Çatalhöyük 1993-1995*. Ankara: British Institute of Archaeology at Ankara, 19-40.

Roberts N., Reed J., Leng M., Kuzucuoğlu C., Fontugne M., Bertaux J., Woldring H., Bottema S., Black S., Hunt E. & Karabıyıkoğlu M. 2001. The tempo of Holocene climate change in the eastern Mediterranean region: new high-resolution crater-lake sediment data from central Turkey. *The Holocene 11,* 721-736.

Roberts N. & Rosen A. 2009. Diversity and complexity in early farming communities of southwest Asia: new insights into the economic and environmental basis of Neolithic Çatalhöyük. *Current Anthropology 50,* 393-402.

Rohling E. & Pälike H. 2005. Centennial-scale climate cooling with a sudden cold event around 8200 years ago. *Nature 434,* 975-979.

Rollefson G. 1986. Neolithic 'Ain Ghazal (Jordan): ritual and ceremony, II. *Paléorient 12, 45-52.*

Rollefson G. 1989. The Late Aceramic Neolithic of the Levant. *Paléorient 15,* 168-173.

Rollefson G.& Köhler-Rollefson I. 1989. The collapse of the Early Neolithic settlements in the Southern Levant. In (Ed.) Hershkovitz I. *People and culture in change.* Oxford: British Archaeological Reports (International Series) 508, 73-90.

Rollefson G. & Köhler-Rollefson I. 1993. PPNC adaptations in the first half of the 6th millennium BC. *Paléorient 19,* 33-42.

Rollefson G. & Simmons A. 1988. The Neolithic settlement at 'Ain Ghazal. In (Eds.) Garrard A. & Gebel H. *The Prehistory of Jordan.* Oxford: British Archaeological Reports (International series) 396, 393-421.

Rosa H. & Bryant M. 2003. Seasonality of reproduction in sheep. *Small ruminant research 48,* 155-171.

Rosen A. 2005. Phytolith indicators of plant and land use at Çatalhöyük. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*. Cambridge & Ankara: McDonald Institute for Archaeological Research & British Institute at Ankara, 203-212.

Rosen A. & Roberts N. 2005. The nature of Çatalhöyük: people and their changing environments on the Konya Plain. In (Ed.) Hodder I. *Çatalhöyük perspectives: reports from the1995-99 season*. Cambridge & Ankara: McDonald Institute for Archaeological Research & British Institute at Ankara, 39-54.

Rosen A. & Weiner S. 1994. Identifying ancient irrigation: a new method using opaline phytoliths from emmer wheat. *Journal of Archaeological Science 21,* 125-132.

Rosenberg M., Nesbitt M., Redding R. & Strasser T. 1995. Hallan Çemi Tepesi: some preliminary observations concerning Early Neolithic subsistence behaviours in Eastern Anatolia. *Anatolica 21,* 2-12.

Rossignol-Strick M. 1999. The Holocene climatic optimum and pollen records of sapropel 1 in the eastern Mediterranean, 9000 -6000 BP. *Quaternary Science Reviews 18,* 515-530.

Rowley-Conwy P. 2000. Milking caprines, hunting pigs: the Neolithic economy of Arene Candide in its West Mediterranean context. In (Ed.) Rowley-Conwy P. *Animal bones, human societies.* Exeter: Short Run Press, 124-132.

Rozanski K. 1985. Deuterium and ^{18}O in European groundwaters – links to atmospheric circulation in the past. *Chemical Geology 52,* 349-363.

Rozanski K., Araguas-Araguas L. & Gonfiantini R. 1992. Relation between long-term trends of ^{18}O isotope composition of precipitation and climate. *Science 258*, 981-985.

Rozanski K., Araguas-Araguas L. & Gonfiantini R. 1993. Isotopic patterns in modern global precipitation. Climate change in continental isotopic records. *American Geophysics Union, Geophysics Monograph 78*, 1-36.

Russell K. 1988. *After Eden*. Oxford:British Archaeological Reports(International Series) 391.

Russell N. 2005. Çatalhöyük worked bone. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 339-368.

Russell N. 2007a. Çatalhöyük worked bone 2007. *Çatalhöyük 2007 archive report.* www.catalhoyuk.com, 170-180. (Retrieved on 23.07.09).

Russell N. 2007b. The domestication of anthropology. In (Eds.) Cassidy R. & Mullin M. *Where the wild things are now: domestication reconsidered*. Oxford: Berg, 27-48, 35.

Russell N. 2008. Çatalhöyük worked bone 2008. *Çatalhöyük 2008 archive report.* www.catalhoyuk.com, 123-128. (Retrieved on 23.07.09).

Russell N. & Düring B. 2006. Worthy is the lamb: a double burial at Neolithic Çatalhöyük (Turkey). *Paléorient 32*, 73-84.

Russell N. & McGowan K. 2003. Dance of the cranes: crane symbolism at Çatalhöyük and beyond. *Antiquity 77*, 445-455.

Russell N. & McGowan K. 2005. Çatalhöyük bird bones. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 99-110.

Russell N. & Martin L. 2005. Çatalhöyük mammal remains. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 33-98.

Russell N. & Meece S. 2005. Animal representations and animal remains at Çatalhöyük. In (Ed.) Hodder I. *Çatalhöyük perspectives: themes from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 209-231.

Ryan P. 2010. (Unpublished PhD thesis). *Diversity of plant and land use in the near eastern Neolithic: phytolith perspective from Çatalhöyük.* Institute of Archaeology: University College, London.

Ryder M. 1983. *Sheep and man.* London: Gerald Duckworth.

Sakae T. & Hirai G. 1982. Calcification and crystallization in bovine enamel. *Journal of Dental Research 61,* 57-59.

Salzman P. 2004. *Equality, hierarchy, and the state.* Boulder: Westview Press.

Saña i Seguí M. 1999. *Arqueològia de la domesticación animal. La gestión de los recuros animals en Tell Halula (Valle del Eufrates-Siria) del 8800 al 7000 BP*. Universitat Autònama de Barcelona: Treballs d'Arquelògia del Pròxim Orient.

Saña i Seguí M. 2000. Animal resource management and the process of animal domestication at Tell Halula (Euphrates Valley, Syria) from 8800 BP to 7800 BP. In (Eds.) Mashkour M., Choyke A., Buitenhuis H. & Poplin F. *Archaeozoology of the Near East IV: proceedings of the fourth international symposium on the archaeozoology of Southwestern Asia and adjacent areas.* Groningen: ARC Publications, 242-256.

Saña i Seguí M. & Helmer D. 1999. The process of animal domestication in the north of the Euphrates valley (Syria): socio-economic implications. In (Eds.) del Olmo Lete G. & Montero-Fenellós J-L. *Archaeology of the Upper Syrian Euphrates: the Tishrin dam area*. Proceedings of the International Symposium held at Barcelona, January 28th-30th 1998. Barcelona: Editorial Ausa, 257-269.

Sanson G., Kerr S. & Gross K. 2007. Do silica phytoliths really wear mammalian teeth? *Journal of Archaeological Science 34*, 526-531.

Schaller G. 1977. *Mountain monarchs: wild sheep and goat of the Himalaya.* Chicago & London: University of Chicago Press.

Schmidt K. 1996. Göbekli Tepe and the Early Neolithic sites of the Urfa region: a synopsis of new results and current views. *Neo-Lithics 1*, 9–11.

Schmidt, K. 2001. Göbekli Tepe, Southeastern Turkey: a preliminary report on the 1995-1999 Excavations. *Paléorient* 26, 45-54.

Schmidt-Nielsen K. 1964. *Desert animals*. Oxford: Clarendon Press.

Schoeninger M. 1995. Stable isotope studies in human evolution. *Evolutionary Anthropology 4*, 83-98.

Scholes R. & Archer S. 1997. Tree-grass interactions in savannas. *Annual Review of Ecological Systematics 28,* 517-544.

Semprebon G., Janis C. & Solounias N. 2004. The diets of the Dromomerycidae (Mammalia: Artiodactyla) and their response to Miocene vegetation change. *Journal of Vertebrate Paleontology* 24, 427-444.

Shackleton D. & Shank C. 1984. A review of the social behaviour of feral and wild sheep and goats. *Journal of Animal Science 58,* 500-509.

Sharma S., Joachimski M., Tobschall H., Singh I., Tewari D. & Tewari R. 2004. Oxygen isotopes of bovid teeth as archives of paleoclimatic variations in archaeological deposits of the Ganga plain, India. *Quaternary Research 62*, 19-28.

Sharp Z. & Cerling T. 1998. Fossil isotope records of seasonal climate and ecology: Straight from the horse's mouth. *Geology 26*, 219-222.

Sheldon K. 2009. (Unpublished MSc dissertation). *Separation of sheep and goat remains using morphometric analysis of metapodials*. Institute of Archaeology, University College, London.

Sherratt A. 1981. Plough and pastoralism: aspects of the secondary products revolution. In (Eds.) Hodder I., Isaac G. & Hammond N. *Patterns of the past.* Cambridge: Cambridge University Press, 261-305.

Sherratt A. 1983. The secondary exploitation of animals in the Old World. *World Archaeology 15,* 90-104.

Sidell J. & Scudder C. 2005. The eggshell from Çatalhöyük: a pilot study. In (Ed.) Hodder I. *Inhabiting Çatalhöyük: reports from the 1995-1999 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 117-122.

Siegenthaler U. & Oeschger H. 1980. Correlation of ^{18}O in precipitation with temperature and altitude. *Nature 285*, 314-317.

Silanikove N. 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock Production Science 67*, 1-8.

Simao Neto M., Jones R. & Ratcliff D. 1987. Recovery of pasture seed ingested by ruminants, 1. Seed of six tropical pasture species fed to cattle, sheep and goat. *Australian Journal of Experimental Agriculture 27,* 239-246.

Simmons A. 1997. Ecological changes during the Late Neolithic in Jordan: a case study. In (Eds.) Gebel H., Kafafi Z. & Rollefson G. *The prehistory of Jordan, II. Perspectives from 1997.* Studies in early Near Eastern production, subsistence and environment 4. Berlin: ex oriente, 309-318.

Simmons A. 2000. Village on the edge; regional settlement change and the end of the Levantine Pre-Pottery Neolithic. In (Ed.) Kuijt I. *Life in Neolithic farming communities; social organisation, identity and differentiation*. New York: Kluwer Academic, 211-233.

Sinclair A. 2000. Adaptation, niche partitioning and co-existence of African bovidae; clues to the past. In (Eds.) Vbra E. & Schaller G. *Antelopes, deer and relatives.* Connecticut: Yale University Press, 247-260.

Smith B. 2007. Niche construction and the behavioural context of plant and animal domestication. *Evolutionary Anthropology 16*, 188-199.

Smith P. 1983. Ganj Dareh: an early Neolithic site in Iran. *Archiv für Orientforschung 29*, 300-302.

Solounias N., Fortelius M. & Freeman P. 1994. Molar wear rates in ruminants: a new approach. *Annales Zoologici Fennici 31*, 219-217.

Solounias N. & Hayek L-A. 1993. New methods of tooth microwear analysis and application to dietary determination of two extinct antelopes. *Journal of Zoology London 229*, 421-445.

Solounias N. & Moelleken S. 1992. Tooth microwear analysis of *Eotragus sansaniensis* (Mammalia:Ruminantia), one of the oldest known bovids. *Journal of Vertebrate Paleontology 12*, 113-121.

Solounias N. & Semprebon G. 2002. Advances in the reconstruction of ungulate ecomorphology with application to early fossil equids. *American Museum Novitates 3366*, 1-49.

Sperling L. & Galaty J. 1990. Cattle, culture and economy: dynamics in East African pastoralism. In (Eds.) Galaty J. & Johnson D. *The world of pastoralism: herding systems in comparative perspective.* New York: Guildford Press, 69-98.

Speth J. & Spielmann K. 1983. Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *Journal of Anthropological Archaeology 2*, 1-31.

Squires V. 1975. Ecology and behaviour of domestic sheep (*Ovis aries*): a review. *Mammalian Review 5*, 35-57.

Stamfli H. 1983. The fauna of Jarmo. In (Eds.) Braidwood L., Braidwood R., Howe B., Reed C. & Watson P. *Prehistoric archaeology along the Zagros flanks.* Chicago: The Oriental Institute, 431-484.

Stein G. 1989. Strategies of risk reduction in herding and hunting systems of Neolithic Southeast Anatolia. In (Eds.) Crabtree P., Campana D. & Ryan K. *Early animal domestication and its cultural context.* MASCA Research Papers in Science and Archaeology. Philadelphia: The University Museum of Archaeology and Anthropology, 87-97.

Stevanović M. & St.George I. 2005. Architecture. *Çatalhöyük 2005 archive report*. www.catalhoyuk.com, 229 -241. (Retrieved on 06.07.09).

Stuiver M., Grootes P. & Braziunas T. 1995. The GISP $\delta^{18}O$ climate record of the past 16,500 years and the role of the sun, ocean and volcanoes. *Quaternary Research 44*, 341-354.

Stuiver M. & Reimer P. 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. *Radiocarbon 35*, 215-230.

Suga S. 1982. Progressive mineralization pattern in developing enamel during the maturation stage. *Journal of Dental Research 61 (special issue)*, 1532-1542.

Teaford M. 1994. Dental microwear and dental function. *Evolutionary Anthropology 17*, 17-30.

Teaford M. 2007. What do we know and not know about dental microwear and diet? In (Ed.) Ungar P. *Evolution of the human diet.* Oxford: Oxford University Press, 106-131.

Teaford M. & Walker A. 1984. Quantitative differences in dental microwear between primate species with different diets and a comment on the presumed diet of *Sivapithecus*. *American Journal of Physical Anthropology* 64, 191-200.

Terrell J., Hart J., Barut S., Cellinese N., Curet A., Denham T., Kusimba C., Latinis K., Oka R., Palka J., Pohl M., Pope K., Williams P., Haines H. & Staller J. 2003. Domesticated landscapes: the subsistence ecology of plant and animal domestication. *Journal of Archaeological Method and Theory 10,* 323-368.

Thissen L. 2001. Time trajectories for the Neolithic of Central Anatolia. In (Eds.) Thissen L. & Gérard F. *The Neolithic of Central Anatolia: internal developments and external relations during the 9th-6th millennia cal. BC.* Proceedings of the International Central Anatolia Neolithic e-Workshop (CANeW) table ronde. Istanbul: Ege Yayınları, 13-26.

Thissen L. 2007. *CANeW Central Anatolia and Cilicia ^{14}C Chart*. www.canew.org (Retrieved on 16.3.07).

Thissen L. & Bischoff D. 2006. *CANeW Upper Mesopotamia ^{14}C Chart* www.canew.org. (Retrieved on 12.2.06).

Thomas E., Wolff E., Mulvaney R., Steffensen J., Johnsen J., Arrowsmith C., White J., Vaughn B. & Popp T. 2007. The 8.2 ka event from Greenland ice cores. *Quaternary Science Reviews 26,* 70-81.

Tornero C. & Saña i Seguí M. 2008. $\delta^{13}C$ and $\delta^{18}O$ results from bioapatite enamel of *Bos* sp. in recent PPNB tell Halula site (Syria, middle Euphrates valley) during 7,800-7,300 cal. BC: considerations related with the origin of the first herding strategies. *Poster presentation to BANEA 2008.* Liverpool February 2008.

Tringham R. 1991. Households with faces: the challenge of gender in prehistoric architectural remains. In (Eds.) Gero J. & Conkey M. *Engendering archaeology: women and prehistory*, Oxford: Basil Blackwell, 93-131.

Türkcan A. 2005a. Some remarks on Çatalhöyük stamp seals. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara 175-186.

Türkcan A. 2005b. *Clay stamp seals.* Çatalhöyük 2005 archive report. www.catalhoyuk.com, 189-191. (Retrieved on 29.07.09).

Twiss K. 2006. A modified boar skull from Çatalhöyük. *Bulletin of the American School of Oriental Research* 342, 1-12.

Twiss K., Bogaard A., Bogdan D., Carter T., Charles M., Farid S., Russell N., Stevanović M., Yalman N. & Yeomans L. 2008. Arson or accident? The burning of a Neolithic house at Çatalhöyük, Turkey. *Journal of Field Archaeology 33,* 41-57.

Twiss K., Russell N. & Orton D. 2010 (manuscript). *Çatalhöyük faunal publication 2010: general overview*.

Uerpmann H-P. 1987. *The ancient distribution of ungulate mammals in the Middle East.* Wiesbaden: Dr. Ludwig Reichert Verlag.

Uerpmann H-P. 1996. Animal domestication – accident or intention? In (Ed.) Harris. D. *The Origins and spread of agriculture and pastoralism in Eurasia*. Washington: Smithsonian Institution Press, 227-237.

Ungar P. 2002. *Microwear Image Analysis Software Version 4.02 (04.10.02) Buffalo Edition*. (Retrieved 10.01.05).

Ungar P., Brown C., Bergstrom T. & Walker A. 2003. Quantification of dental microwear by tandem scanning confocal microscopy and scale-sensitive fractal analysis. *Scanning 25,* 185-193.

Ungar P. & Scott R. 2007. *Microwear texture analysis as applied to fossil primates and human ancestors*. 8th International Congress of Vertebrate Morphology (ICVM-8), Paris, 16th–21st July 2007. icvm8.snv.jussieu.fr (Retrieved on 14.01.10).

Valamoti S. 2007. Detecting seasonal movement from animal dung: an investigation in Neolithic northern Greece. *Antiquity 81,* 1053-1064.

Vanpoucke S., Mainland I., de Cupere B. & Waelkens M. 2009. Dental microwear study of pigs from the classical site of Sagalassos (SW Turkey) as an aid for the reconstruction of husbandry practices in ancient times. *Environmental Archaeology 14*, 137-154.

Verhoeven M. 2004. Beyond boundaries: nature, culture and a holistic approach to domestication in the Levant. *Journal of World Prehistory 18*, 179-282.

Verhoeven M. 2005. Ethnoarchaeology, analogy, and ancient society. In (Eds.) Pollock S. & Bernbeck R. *Archaeologies of the Middle East: critical perspectives.* Oxford: Blackwell, 251-27.

Vigne J-D., Buitenhuis H. & Davis S. 1999. Les premiers pas de la domestication animale à l'oest de l'Euphrate: Chypre et l'Anatolie centrale. *Paléorient 25*, 49-62.

Vigne J-D., Carrère I., Saliége J-F., Person A., Bocherens H., Guilaine J. & Brios J. 2000. Pre-domestic cattle, sheep, goat and pig during the late 9th and the 8th millennium cal. BC on Cyprus: preliminary results of Shillourokambos (Parekklisha, Limassol). In (Eds.) Mashkour M., Choyke A., Buitenhuis H. & Poplin F. *Archaeozoology of the Near East IV: proceedings of the fourth international symposium on the archaeozoology of Southwestern Asia and adjacent areas.* Groningen: ARC Publications, 83-106.

Vigne J-D. & Helmer D. 2007. Was milk a 'secondary product' in the Old World Neolithisation process? Its role in the domestication of cattle, sheep and goats. *Anthropozoologica 42,* 9-40.

Walker A., Hoek H. & Perez L. 1978. Microwear of mammalian teeth as an indicator of diet. *Science 201,* 908-910.

Wallace M. 2007. Ethnoarchaeological work on sheep dung and application to selected samples from Çatalhöyük. *Çatalhöyük 2007 archive report*. www.catalhoyuk.com, (Retrieved on 01.08.10).

Wang Y. & Cerling T. 1994. A model of fossil tooth and bone digenesis implications for paleodiet reconstruction from stable isotopes. *Palaeogeography, Palaeoclimatology, Palaeoecology 107,* 281-289.

Wasse A. 1997. Preliminary results of an analysis of the sheep and goat bones from 'Ain Ghazal, Jordan. In (Eds.) Gebel H., Kafafi Z. & Rollefson G. *The prehistory of Jordan, II. Perspectives from 1997.* Studies in early Near Eastern production, subsistence and environment 4. Berlin: ex oriente, 575-592.

Wasse A. 2007. Climate, economy and change: Cyprus and the Levant during the Late Pleistocene-Mid Holocene. In (Ed.) Clarke J. *On the margins of Southwest Asia: Cyprus during the 6th to 4th millennia BC.* Oxford: Oxbow Books, 43-63.

Watkins T. 1996. Excavations at Pınarbaşı: the early stages. In (Ed.) Hodder I. *On the surface: Çatalhöyük 1993-95*. (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 47-57.

Watson J. 1979. The estimation of the relative frequencies of mammalian species: Khirokitia 1972. *Journal of Archaeological Sciences 6*, 127-137.

Watson P. 1979. *Archaeological ethnography in western Iran.* Viking Fund Publications in Anthropology 57. Arizona: University of Arizona Press.

Webb S. 1983. The rise and fall of the Late Miocene ungulate fauna in North America. In (Ed.) Nitecki M. *Co-evolution.* Chicago: University of Chicago Press, 267-306.

Weinreb M. & Sharav Y. 1964. Tooth development in sheep. *American Journal of Veterinary Research 25*, 891-908.

Wendrich W. 2005. Çatalhöyük basketry. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons.* (McDonald Institute Monographs). Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 333-338.

Weninger B., Alram-Stern E., Bauer E., Clare L., Danzeglocke U., Jöris O., Kubatzki C., Rollefson G., Todorova H. & van Andel T. 2006. Climate forcing due to the 8200 cal. yr. BP event observed at Early Neolithic sites in the eastern Mediterranean. *Quaternary Research 66,* 401-420.

Wick L., Lemcke G. & Sturm M. 2003. Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: high resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey. *The Holocene 13,* 665-675.

Wiedmann F., Bocherens H., Mariotti A., von den Driesch A. & Grupe G. 1999. Methodological and archaeological implications of intra-tooth isotopic variations ($\delta^{13}C$, $\delta^{18}O$) in herbivores from 'Ain Ghazal (Jordan, Neolithic). *Journal of Archaeological Science 26*, 697-704.

Wiens J. 1985. Vertebrate responses to environmental patchiness in arid and semiarid ecosystems. In *The ecology of natural disturbance and patch dynamics.* New York: Academic Press, 169-193.

Wilcox G., Fornite S. & Herveux L. 2008. Early Holocene cultivation before domestication in northern Syria. *Vegetation History and Archaeobotany 17,* 313-325.

Wilkie T., Mainland I., Albarella U., Dobney K. & Rowley-Conwy P. 2007. A dental microwear study of pig diet and management in Iron Age, Romano-British, Anglo-Scandinavian, and Medieval contexts in England. In (Eds.) Albarella U., Dobney K., Ervynck A. & Rowley-Conwy P. *Pigs and humans: 10,000 years of interaction.* Oxford: Oxford University Press, 241-254.

Woldring H. 2002. The early Holocene vegetation of central Anatolia and the impact of farming. In (Eds.) Cappers R. & Bottema S. *The dawn of farming in the Near East*. Berlin: ex oriente, 39-48.

Wright K. 2005. Stone bead technology at Çatalhöyük: summer 2005. *Çatalhöyük 2005 archive report.* www.catalhoyuk.com, 226-228. (Retrieved on 09.07.09).

Wright K. 2006. Bead technology at Çatalhöyük. *Çatalhöyük 2006 archive report*. www.catalhoyuk.com, 280-283. (Retrieved on 09.07.09).

Wright K. & Bains R. 2007. Bead technology at Çatalhöyük. *Çatalhöyük 2007 archive report.* www.catalhoyuk.com, 316-322. (Retrieved on 09.07.09).

Wright K., Critchley P. & Garrard A. 2008. Stone bead technologies and early craft specialization: insights from two Neolithic sites in eastern Jordan. *Levant 40,* 131-165.

Wright K. & Garrard A. 2003. Social identities and the expansion of stone bead-making in Neolithic Western Asia: new evidence from Jordan. *Antiquity 77,* 267-284.

Yakir D. 1992. Variations in the natural abundance of oxygen-18 and deuterium in plant carbohydrates. *Plant Cell Environment 15,* 1005-1020.

Yurtsever Y. & Gatt J. 1981. Atmospheric waters. In (Eds.) Gatt J. & Gonfiantini. *Stable isotope hydrology.* IAEA Technical Report Series 210, 103-142.

Zarazaga L., Guzmán J., Domínguez C., Pérez M. & Prieto R. 2005. Effect of plane of nutrition on seasonality of reproduction in Spanish Payola goats. *Animal Reproduction Sciences 87,* 253-267.

Zazzo A., Mariotti A., Lécuyer C. & Heintz E. 2002. Intra-tooth isotope variations in late Miocene bovid enamel from Afghanistan: paleobiological, taphonomic, and climatic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology 186,* 145-161.

Zeder M. 1978. Differentiation between the bones of caprines from different ecosystems in Iran by the analysis of osteological microstructure and chemical composition. In (Eds.) Meadow R. & Zeder M. *Approaches to Faunal Analyses in the Middle East*. Peabody Museum of Archaeology and Ethnology Bulletin 2. Harvard: Harvard University, 69-84.

Zeder M. 1999. Animal domestication in the Zagros: a review of past and current research. *Paléorient 25*,11-25.

Zeder M. 2005. A view from the Zagros: new perspectives on livestock domestication in the Fertile Crescent. In (Eds.) Vigne J-D., Peters J. & Helmer D. *First steps of animal domestication: new zoological approaches.* Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham, August 2002. Oxford: Oxbow, 125-146.

Zeder M. 2006. A critical assessment of markers of initial domestication in goats (*Capra hircus*). In (Eds.) Zeder M., Bradley D., Emshwiller E. & Smith B. *Documenting domestication: new genetic and archaeological paradigms.* Los Angeles: University of California Press, 181-208.

Zeder M. 2007. Central questions in the domestication of plants and animals. *Evolutionary Anthropology 15*, 105-117.

Zeder M. 2009. The Neolithic macro-(R)evolution: macroevolutionary theory and the study of culture change. *Journal of Archaeological Research 17*, 1-63.

Site	*Temporal relationship to Çatalhöyük*		*Location*	*Altitude (masl)*	*Size (ha)*	*Environmental setting*	*Rain (mm)*	*Plant use*	*Settlement and buildings*	*Tools and ceramics*	*Socio-ritual*	*Excavation date*	*Site reports*
	Ante-cedent	*Con-tempor-aneous*											
Çayönü	■	■	Upper Tigris	832	5.6	River plain, between steppe and oak parkland	C 300	Gathering wild grains and pulses at start, domestic wheat, pulses thereafter	Houses with changes over time (see phasing labels)	Ceramic in later two phases	Public buildings in each phase, skull houses, and under floor burials. Quadruped figurines in last phase only.	1964-1992	Özdoğan 1977; Çambel & Braidwood 1980
Nevalı Çori		■	Urfa plateau/ Harran Plains	490	0.36	Spur between 2 wadis	>480	Domestic wheats and pulses and wild foods	Early channelled houses , giving way to non-channelled houses in later phases	Mainly flint chipped stone, ground stone tools, bowls, Aceramic	Cult building, stone carvings, roasting pit and skull burials in earliest phase, figurines, beads, bracelets	1982-1992	Hauptmann 1999
Cafer		■	E. Taurus mountains	670	0.42	Wide valley in fertile plain, oak park, *Artemesia* steppe	350 - 400	Probably domestic, wheats becoming more important than pulses over time	Rectangular rooms in mudbrick buildings with clay floors, give way to cell plan rooms then larger houses	PPNB chipped stone, ground stone bowls & tools, worked bone, Aceramic	Skulls absent from burials in earliest phase, under floor burials. 4 figurines, none mammalian	1964-1991	Özdoğan 1977; Çambel & Braidwood 1980
Gritille			Urfa plateau/ Harran Plains	418	0.32	By spring on river terrace, near oak parkland	400-600	Domestic wheats becoming more important than pulses over time	Mudbrick on stone foundations, painted and plastered	PPNB chipped stone, mainly flints, ground stone, worked bone, Aceramic except upper level	Figurines, gaming pieces, cylindrical stamps, stone & bone beads	1981-1984	Ellis &Voigt 1981
Gürcütepe			Urfa plateau/ Harran Plains	800	3.1	By karstic spring on alluvium, barren limestone	>480	No evidence	Rectangular houses, stone foundations	PPNB obsidian & flint chipped stone, ground stone, Aceramic until upper level	Public building, figurines	1995-1996	Hauptmann 1999; Schmidt 1996; 2001

Appendix 1
Southeast Anatolia settlements discussed: a summary of the main findings

Site	*Temporal relationship to Çatalhöyük*						*Location*	*Altitude (masl)*	*Size (ha)*	*Environmental setting*	*Rain (mm)*	*Plant use*	*Settlement and buildings*	*Tools and ceramics*	*Socio-ritual*	*Excavation date*	*Site reports*
	Ante-cedent			*Con-tempor-aneous*													
Ganj Dareh								1350	0.13	River edge, oak pistachio	300-500	Wild earlier, domestic later, mortars	Earliest possibly seasonal, then rectangular, mudbrick, hard lime, storage bins	Early ceramics, flint chipped stone only, ground stone, exotic shell beads	Below floor burials, cranial deformations, wild sheep skulls in niches, figurines	1960's 1970's	Smith P. 1983
Ali Kosh							Deh Luran Plain	200	1.4	Rolling semi-arid steppe, oak parkland hill slopes	350	Domesticated wheat, wild *Prosopis*, pulses, flax	Early –un-plastered houses of mud slabs, no heaths or ovens, later more established plastered mudbrick houses, stone foundations, hearths, matting, baskets	Ground stone, chipped stone mainly flint, bone tools, Aceramic earlier, later decorated pottery, spindle whorls	Turquoise & shell jewellery, copper, under floor burials, no mat shrouds, figurines –animal early, human & abstract late	1961-3	Hole *et al.* 1969
Tepe Sarab							Highland Iran.	1300	?	River edge, oak pistachio	300-500	No domestic plants or tools	Early camp, later slab mud buildings	Ground stone, chipped stone bone tools, ceramic	Clay figurines – animal and human	1950's	Braidwood & Howe 1960
Jarmo							Highland Iraq, oak pistachio parkland	800	1.3	Wadi banks	>250	Domestic grains and pulses, querns	Houses cobble floors, painted, plastered, roof entrance (?), reed roofing, indoor hearths, ovens, storage bins, matting	Aceramic/ early ceramic, PPNB chipped stone obsidian, clay balls, ground stone, spindle whorls, bone tools	Burials mostly outside, figurines, stamp seals, beads	1948-55	Braidwood 1983

Appendix 2
Zagros settlements discussed: a summary of the main findings

Site	*Temporal relationship to Çatalhöyük*		*Location*	*Altitude (masl)*	*Size (ha)*	*Environmental setting*	*Rain (mm)*	*Plant use*	*Settlement and buildings*	*Tools and ceramics*	*Socio-ritual*	*Excavation date*	*Site reports*
	Ante-cedent	*Con-tempor-aneous*											
Aswad	■	■	Damascene Basin	600	5	Oasis lakeshore, in steppe	<150	Domesticated wheat, later barley & legumes, flax	No architecture, pits, wattle & daub	Bone tools, PPNB chipped stone, more obsidian, clay balls.	Burial with figurine, mudbrick platform, many figurines including large females	Late 60's-early 70's	De Conteson 1983
Ghoraifé	■	■	Damascene Basin	600	5	Oasis lakeshore, in steppe	c.200	Domesticated plants	Pits, wattle & daub & mudbrick, clay balls	PPNB chipped stone more obsidian, bone tools	Cylinders, some figurines	Late 60's-early 70's	De Conteson 1983
Halula	■	■	Middle Euphrates Valley	460	7	Oasis valley, in steppe	<200	Domestic cereals & legumes from outset. Grass and reed matting	Single storey, mudbrick, rectangular, ovens, storage bins, hard lime plastered, painted floors	PPNB chipped stone, 6% then 32% obsidian, ground stone, worked bone, seals	Public walled terrace, figurative paintings on floor, burials in matting, stone & bone beads	1996 2000	Akkermans & Schwarz 2003
Abu Hureyra	■	■	Middle Euphrates Valley	285	11.5	River terrace near steppe and parkland	<200	Domestic barley, possibly 11th mill BC, definite later cereal & legume introductions, grass etc matting	Closely spaced but separate rectangular houses, hard lime plastered and painted with hearths, bins	PPNB chipped stone, <4% obsidian, bone tools, ground stone, worked bone, pottery later	Burial in matting with horn-cores, skull house, secondary multiple burials, plastered & painted skeleton, stone & bone beads	1972-3	Moore *et al.* 2000
Bouqras		■	Middle Euphrates Valley	200	2.75	River terrace	<150	Very little cereal, barley, flax, grass and reed matting	Aligned, single storey, mudbrick, rectangular, ovens, storage bins, hard lime plastered, painted floors	PPNB chipped stone, ground stone, worked bone, pottery in late (7-1) levels, seals	Crane paintings, stone & bone beads	1976-1978	Akkermans *et al.* 1982

Appendix 3

North Levant settlements discussed: a summary of the main findings

Site	*Temporal relationship to Çatalhöyük*		*Location*	*Altitude (masl)*	*Size (ha)*	*Environmental setting*	*Rain (mm)*	*Plant use*	*Settlement and buildings*	*Tools and ceramics*	*Socio-ritual*	*Excavation date*	*Site reports*
	Ante-cedent	*Con-tempor-aneous*											
Shillouro-kambous	■		South Cyprus coast	<50	0.5	Hill-slopes, 5km from coast	400-500	Grindstones, introduced domestic grains	Early pits, then stone built buildings	Epi-Palaeolithic with PPNB chipped stone, ground stone Aceramic	Enclosures and wells, skull burials, collective burial with animal remains, individual burials, kitten burial,	1992 - 2004	Guilaine & Briois 2001
Khirokitia		■	South Cyprus coast	200	<1	Hill-slopes, 7km from coast	400-500	Introduced domestic grains, grindstones	Heavy walled circular buildings with plastered pillars. Some grouped and enclosed.	PPNB chipped stone, Aceramic, stone bowls	Under floor individual burials with animal part grave goods, cranial deformations, lamb burials, figurines, carved pebbles, jewellery, splayed animal relief on stone bowl.	1977 1987	LeBrun 1994

Appendix 4
Cyprus settlements discussed: a summary of the main findings

Site	*Temporal relationship to Çatalhöyük*		*Location*	*Altitude (masl)*	*Size (ha)*	*Environmental setting*	*Rain (mm)*	*Plant use*	*Settlement and buildings*	*Tools and ceramics*	*Socio-ritual*	*Excavation date*	*Site reports*
	Ante-cedent	*Con-tempor-aneous*											
Jericho	■	■	Judean Hills	-250	4	River valley, oak parkland slopes and steppe	>200	Domestic grains and pulses, flax from outset, rushes and reeds for matting.	Round mudbrick houses in first phase, then rectangular	PPNB chipped stone mainly flints, pottery ground stone, spindle whorls, bone tools	First phase -enclosing wall and tower, then under floor burial, plaster skulls	1952-58	Kenyon 1957
Yiftah'el		■	Lower Galilee	145	1.5?	Valley in open park/oak forest	>200	Domesticated lentils only.	Rectangular buildings, hard limestone floors and walls, hearths concentrated outside settlement	PPNB chipped stone mainly flints, ground stone, bone tools	Bone, shell and local stone beads	1990s -	Garfinkel 1985; Braun 1997
'Ain Ghazal			Jordanian Hills	725	12	Wadi oasis, in steppe and oak parkland	250	Domestic pulses, some grains, flax disappear in last two phases, barley returns last phase	Rectangular slab and cobble houses, mud plaster, only a camp in penultimate phase and subterranean seasonal houses in last phase	Aceramic throughout, bone tools, typical PPNB chipped stone, declining by EN	Under floor burials, cached plastered statues & skulls in third phase, special buildings, local &exotic beads, figurines	1982-6	Rollefson 1986; Rollefson & Simmons 1988
Azraq 31			Eastern Jordan	530	0.43	Oasis on moist/arid steppe margin	50	Cultivated barley	Seasonal camp round slab buildings until rectangular in last phase, storage bins, hearths, platforms	PPNB chipped stone, ground stone	Beads, increasing variety	1982-1989	Garrard *et al.* 1987

Appendix5

South Levant settlements discussed: a summary of the main findings

Site	*Temporal relationship to Çatalhöyük*						*Location*	*Altitude (masl)*	*Size (ha)*	*Environmental setting*	*Rain (mm)*	*Plant use*	*Settlement and buildings*	*Tools and ceramics*	*Socio-ritual*	*Excavation date*	*Site reports*
	Ante-cedent			*Con-tempor-aneous*													
Aşıklı Höyük		■	■				Cappadocia	1190	3.45	Sheltered river valley, barren tuff plateaux	330	Grinding stones for domestic grains. Plus wild plants	Separate, rectangular, mudbrick, roof entrance, plastered, hearths	Chipped obsidian blades dominate, ground stone	Figurines, beads, under house-floor, inter-mural burials. Separate public areas	1969, 2006	Esin 1999
Boncuklu			■				Konya Plain	*c*.1000	1.0	Alluvial fan in lake basin	Rain-fed	Domesticated cereals	Ovoid, mudbrick, plastered, painted red	Aceramic, microliths, plaster vessels, ground stone	Beads, clay objects, incised stones, wall painting and installations, internal burials, one cranial removal, figurines	2006 -	Baird 2006; 2007; 2008; 2009
Süberde				■			Lake District	1040	0.5	On a ridge near lake alluvium, oak and pine slopes	Rain-fed	Sickles, grindstones, grains and pulses domestic?	Rectangular mudbrick mainly, hearths	Obsidian and flint chipped & ground stone	Human and animal figurines	1960s	Bordaz 1969
Canhasan III				■	■		Konya Plain	900	0.78	Alluvial fan in lake basin	Rain-fed	Domestic grains and pulses, wild plants	Rectangular, slab pisė, painted and plastered, benches, hearths	Mostly obsidian chipped stone, aceramic until later Level	Beads	1972	French *et al*. 1972
Erbaba						■	Lake District	1150	0.5	1.5 km from lake, oak and pine slopes	Rain-fed	Grindstones, domestic grains and pulses	Orientated rectangular houses, mud brick, plastered, roof entrances. Later shared courtyard clusters of buildings	Obsidian and flint chipped stone, ground stone, fine grit tempered ware	Male and female figurines, no installations or monumental architecture	1967-78	Bordaz & Bordaz 1982
Pınarbaşı B						■	Konya Plain	1105	0.25	Lakeside rock shelter, oak parkland, steppe	Rain-fed	Not analysed	Diverse structures evident and ovens, fire-pits	Obsidian, flint, ground stone, bone tools	One child burial	1970s, 2003-	French 1970; Watkins 1996

Appendix 6
Central Anatolia settlements discussed: a summary of the main findings

Çatalhöyük locality	*Water availability*	*Land form*	*Woody taxa*	*Grass taxa*	*Other taxa*
Alluvial fan	Seasonal inflows	Meadows, seasonal ephemeral water areas	Chaste tree, caper	Annual grasses	*Suaeda, Salosa, Atriplex, Beta,*
	Permanent/seasonal water bodies	Pools, marshes, seasonally flooded areas	Alder, reed, tamarisk, poplar	Annual grasses, *Alopecurus, Phalaris, Agropyron*	*Bolboschoenus maritimus, Carex, Phragmites, Potamogeton, Juncus, Eleocharis*
	Edges of rivers and springs	Well-drained areas and river banks	Willow, poplar, elm, ash, tamarisk, vines, plane, chaste tree	Annual grasses, *Taeniatherum caput medusa*	*Capsella*& other *Cruciferae, Erucaria, Helianthemum,Trifolium, Rumex, Alyssum, Stachys, Sisymbrium, Polygonum, Silene, Adonis, Vaccaria pyramidata, Astragalus/ trigonella*
Plains	< 250mm p.a.	Arid steppe		*Eremopyrum, Stipa*	
		Saline depressions	Wormwood, mints	*Aeluropus*	*Suaeda, Salosa, Atriplex, Beta*
Terraces	*c.* 300mm p.a.	Woodland steppe	Almond, pistachio, hackberry, hawthorn, buckthorn, capers, mints	Annual grasses, *Taeniatherum caput medusa*	*Capsella& other Cruciferae, Erucaria, Helianthemum,Trifolium, Rumex, Alyssum, Stachys, Sisymbrium, Polygonum, Silene, Adonis, Vaccaria pyramidata, Astragalus/ trigonella*
Lower hill-slopes	400-600mm p.a.	Oak park-woodland	Deciduous oak, juniper, pear,cherry, plum, hawthorn, almond, hackberry, pistachio, rosebush	Annual grasses, *Taeniatherum caput medusa*	*Capsella& other Cruciferae, Erucaria, Helianthemum,Trifolium, Rumex, Alyssum, Stachys, Sisymbrium, Polygonum, Silene, Adonis, Vaccaria pyramidata, Astragalus/ trigonella*
Upland slopes		Montane forest, dense oak woodland	Pine, juniper, deciduous oak, maple, plums, cherries, rosebush		

Appendix 7
Plant taxa found in Çatalhöyük assemblages, and interpretation of their landscape distribution.
After Asouti (2005, 246); Fairbairn et al. *(2002, 44-46); Fairbairn* et al. *(2005, 142-145)*

Specimen	*Death*	*Diet in weeks before death*	*Side*	*Tooth stage and suggested age (Payne 1973)*				
				M_1	M_2	M_3	*Stage*	
101	Early July	Mid-summer pasture	L	17	16	13	G	4-6 y
102	Early July	Mid-summer pasture	R	17	16	11	G	4-6y
103	May	Spring grass pasture	L	17	17	17	G	4-6 y
104	June	Cereal stubble	L	22	19	19	H	6-8 y
106	Early December	Late pasture	R	17	10	In crypt	E	1-2y
302	Late August	Late pasture	L	Not available	17	Not available	G/H*	4-8 y
410	Early June	Spring grass pasture	R	17	16/17	11	G	3y
409	Early July	Mid-summer pasture	L	17	16/17	17	H	3y
412	Early June	Spring grass pasture	L	17	16	11	G	4y
413	Early October	Late pasture	R	17	16	11	G	5y
415	Early July	Mid-summer pasture	L	17	16	11	G	5y

Appendix 8
Details of modern tooth specimens, including age of death, month of death, diet preceding death and side of body

Identification number			*Side*	*Column height (mm)*	*Tooth stage and suggested age (Payne 1973)*							*Surface condition*
Sample	*Unit number*	*Faunal number*			*Dp_4*	*p_4*	*M_1*	*M_2*	*M_3*	*Stage*	*Suggested age*	
1	1023	F201	R	32.2	16	17	17	14	0	E*	2-3y	2
2	1023	F202	R	27.8	0	0	17	13	0	E*	2-3y	2
3	1038	F75	R	28.5	0	17	17	13	0	E*	2-3y	2
4	1038	F76	R	33.2	16	16	17	13	0	E*	2-3y	2
6	1315	F118	R	29.4	0	93	17	14	0	E*	2-3y	4
7	1511	F283	R	33.7	0	0	17	14	0	E*	2-3y	2
8	1629	F133	R	26.5	0	26	19	17	15	F	3-4y	2
9	2600	F202	L	31.7	0	0	17	13	0	E*	2-3y	2
10	6031	F81	L	31.6	10	0	17	13	2	D*	1-2y	2
12	7813	F416	L	29.4	13	93	17	13	0	E*	2-3y	3
13	8178	F219	R	21.2	0	27	17	17	16	F	3-4y	2
14	8624	F9	R	22.5	0	27	19	17	17	G	4-6y	2
15	8632	F183	R	17.0	0	0	0	17	16	F	3-4y	2
16	10264	X52	R	29.1	0	24	17	14	9	E*	2-3y	3
18	11862	F305	R	24.8	0	27	17	17	0	G*	4-6y	3
19	11897	F11	L	21.0	0	27	20	17	0	H*	6-8y	4
20	12456	F465	L	27.1	0	26	17	17	13	F	3-4y	2
21	12456	F466	L	27.1	0	26	18	18	0	H*	6-8y	3
22	12456	F711	L	18.5	0	27	0	17	17	G	4-6y	3
23	12456	F713	L	14.3	0	0	17	17	17	G	4-6y	3
24	12456	X120	L	27.7	0	26	17	17	13	F	3-4y	3
25	12456	X128	L	27.3	0	21	17	17	8	F*	3-4y	3
26	13079	F276	R	32.0	13	19	17	13	0	E*	2-3y	3
27	13079	F290	R	28.5	0	0	17	14	0	E*	2-3y	3
28	13079	F291	R	28.4	10	0	17	11	0	D*	1-2y	3
29	13098	F49	L	17.7	0	27	19	17	0	G*	4-6y	4
30	13370	X22	R	21.1	0	27	17	16	0	F*	3-4y	?
31	13570	F172	R	21.3	0	0	18	17	17	G	4-6y	3
32	14038	F31	R	22.1	0	26	18	17	17	G	4-6y	4
33	14059	F1	R	19.3	0	27	19	17	17	G	4-6y	2
34	14070	F1	L	25.5	0	0	17	17	10	F*	3-4y	2
35	14071	F2	R	21.2	0	27	0	17	17	G	4-6y	2
36	14183	F11	L	27.5	0	0	18	17	0	G*	4-6y	2
37	14187	F49	R	21.0	0	26	22	17	16	F	3-4y	3
38	14800	F4	L	27.2	0	23	0	16	10	D	1-2y	2
39	14807	F237	L	23.5	0	0	0	17	17	G	4-6y	4
40	14916	F2	R	31.3	0	19	17	13	0	E*	2-3y	3
41	14916	F4	L	29.3	0	27	18	17	0	G*	4-6y	3

Appendix 9

Table showing side, age and condition of each archaeological tooth specimen

Identification number			*Side*	*Column height (mm)*	*Tooth stage and suggested age (Payne 1973)*							*Surface condition*
Sample	*Unit number*	*Faunal number*			*Dp_4*	*p_4*	*M_1*	*M_2*	*M_3*	*Stage*	*Suggested age*	
42	15728	F101	L	20.1	0	27	17	17	13	F*	3-4y	3
43	15820	F86	R	25.7	0	27	17	17	17	G	4-6y	4
44	15820	F88	R	29.5	0	27	17	17	16	F	3-4y	4
45	2000	F29	L	30.6	13	17	17	14	3	D	1-2y	2
47	5290	F2635	R	28.6	0	0	17	13	3	D	1-2y	2
50	5290	F2608	L	31.4	0	26	17	17	11	G	4-6y	2
51	1873	F532	R	20.2	0	27	18	17	16	G	4-6y	2
52	1889	F183	R	25.3	0	26	18	17	94	G	4-6y	2
53	1889	F184	R	24.1	0	0	17	17	13	F	3-4y	3
54	4121	F1833	R	29.4	0	24	17	16	9	D	1-2y	2
55	3740	F389	R	13.9	0	0	0	17	17	G	4-6y	3
56	16262	F64	R	16.8	0	27	23	17	17	G	4-6y	3
57	16262	F100	R	23.0	0	27	18	17	17	G	4-6y	3
58	16262	F65	R	23.5	0	0	0	17	15	F	3-4y	3
59	14572	F76	L	13.3	0	28	23	17	17	G	4-6y	3
60	16262	F102	R	34.5	0	26	18	17	97	G*	4-6y	3
61	16262	F99	L	19.9	0	27	19	17	0	G*	4-6y	3
62	16262	F66	R	30.0	12	0	17	14	0	D*	1-2y	2
63	16262	F108	R	17.1	0	27	20	17	17	G	4-6y	3
64	4838	F627	R	20.7	0	27	17	17	0	G*	4-6y	3
65	5290	F2630	R	23.8	0	27	19	17	0	G*	4-6y	3
66	5290	F2631	R	30.0	13	93	17	14	0	E*	2-3y	2
67	7898	F237	L	30.0	10	0	17	11	0	D*	1-2y	2
68	16262	F103	R	16.4	0	28	23	20	17	H*	6-8y	3
69	14916	F3	R	27.1	0	0	0	16	14	F	3-4y	3
70	15728	F102	L	13.6	0	0	0	20	16	H*	6-8y	3
71	16247	F3	L	23.3	0	27	18	17	15	G	4-6y	None
72	15743	F1220	R	13.9	0	28	23	19	17	H*	6-8y	3
73	17047	F751	R	27.4	0	95	17	16	0	F	3-4y	3
74	17047	F294	R	34.2	13	0	17	13	0	E	2-3y	4
75	17047	F379	L	24.9	0	27	18	17	17	G	4-6y	4
76	15743	F1219	L	in jaw	0	27	18	0	0	D-I*	>1y	3
77	16260	F443	L	in jaw	0	27	23	17	17	G	4-6y	3
78	16260	F444	R	in jaw	0	0	22	17	15	G	4-6y	3

Appendix 9 cont.

Specimen	*Excavation record*			*Faunal record*	
	Category	*Location*	*Description*	*Faunal unit description*	*Mandible weathering*
43	Midden	External	Laminated, ashy	Rapidly deposited midden	Moderate
44	Midden	External	Laminated, ashy	Rapidly deposited midden	Moderate
67	Midden	House infill	Layered	Fairly rapid, midden	Very slight
29	Cluster	Platform (burial) infill	Human & animal bone	Possible re-deposited fill	Moderate
31	Midden	External	Black, silty	Rapid, midden	Slight
26	Infill	Occupation level	Massive, clays	Mixed dirty fill	Slight
27	Infill	Occupation level	Massive, clays	Mixed dirty fill	Slight
28	Infill	Occupation level	Massive, clays	Mixed dirty fill	Slight
12	Make-up	Construction	Brick & midden	mixed dirty fill	Very slight
9	Make-up	Dump	Brown, animal disturbed	Good condition, household waste	Very slight
32	Midden	Infill of pit	Ashy	Rapid (bone articulation)	Moderate
33	Make-up	Dump	Cay, brown	Not re-deposited, v. good condition	Very slight
59	Midden	External	Ashy, laminated	Rapid, midden (articulations)	Slight
77	Midden	External	Layered midden	Slow accumulation, much gnawing	Slight
78	Midden	External	Layered midden	Slow accumulation, much gnawing	Slight
60	Midden	External	Ashy, laminated	Rapid , midden	Slight
57	Midden	External	Ashy, laminated	Rapid , midden	Slight
68	Midden	External	Ashy, laminated	Rapid , midden	Slight
58	Midden	External	Ashy, laminated	Rapid , midden	Slight
56	Midden	External	Ashy, laminated	Rapid , midden	Slight
62	Midden	External	Ashy, laminated	Rapid , midden	Very slight
63	Midden	External	Ashy, laminated	Rapid , midden	Slight
61	Midden	External	Ashy, laminated	Rapid , midden	Slight
42	Midden	External	Ashy, laminated	Rapid midden, some re-deposition	Slight
70	Midden	External	Ashy, laminated	Rapid midden, maybe some re-deposition	Slight

Appendix 10

Table of all specimens showing details of their depositional context

Specimen	*Excavation record*			*Faunal record*	
	Category	*Location*	*Description*	*Faunal unit description*	*Mandible weathering*
21	Activity	External	Ashy, some lamination	Rapid, single source midden	Slight
22	Activity	External	Ashy, some lamination	Rapid, single source midden	Slight
23	Activity	External	Ashy, some lamination	Rapid, single source midden	Slight
24	Activity	External	Ashy, some lamination	Rapid, single source midden	Slight
25	Activity	external	Ashy, some lamination	Rapid, single source midden	Slight
18	Infill	Feasting remains	Clay, some layering	Good condition	Slight
19	Cluster	Feasting remains	Horn ,antler, cattle & fill	Re-deposited midden, not feasting	Moderate
20	Activity	External	Ashy, some lamination	Rapid, single source midden	Slight
69	Midden	Make-up	Laminated, ashy	Rapid (bone articulations)	Slight
40	Midden	Make-up	Laminated, ashy	Rapid (bone articulations)	Slight
41	Midden	Make-up	Laminated, ashy	Rapid (bone articulations)	Slight
16	Cluster	Placed deposit	Mixed, reddish clay silt fill	Articulations, possibly uncooked sheep	Slight
36	Midden	Infill of pit	Ashy, laminated	Rapid, midden	Very slight
37	Midden	Infill of pit	Ashy, laminated	Rapid, midden	Slight
34	Floor surface	Dump	Sandy clay massive	Re-deposited, fill not floor	Very slight
35	Make-up	Dump	Silty, grey-brown compound	Rapid, coherent, midden, unusual bpr	Very slight
73	Midden	External	Finely bedded midden	Rapid, fragile bone intact, low digestion, gnawing	Slight
74	Midden	External	Finely bedded midden	Rapid, fragile bone intact, low digestion, gnawing	Moderate
75	Midden	External	Finely bedded midden	Slow accumulation, much gnawing	Moderate
30	Cluster	Behind oven	Bone and clay, massive fill	Possibly re-deposited, curated	Not recorded
71	Dump	External, floor	Multiple compact with clay	Mixed, much digestion, some abrasion + fresh	None
72	Midden	Trampled surface	Layered midden	Very little gnawing or digestion	Slight
76	Midden	External	Layered, trampled surface	Rapid, very little gnawing or digestion	Slight
38	Infill	Floor surface	Pink brown , massive	Rapid, coherent, articulations, feasting deposit?	Very slight
39	Midden	Make-up	Mixed, grey, massive	Rapid burial, feast assemblage	Moderate

Appendix 10 cont.

Specimen	*Excavation record*			*Faunal record*	
	Category	*Location*	*Description*	*Faunal unit description*	*Mandible weathering*
14	Midden	External	Ashy, laminated	Good surface condition	Slight
13	Midden	External	Black, layered	Midden -like	Slight
15	Midden	Make-up	Mixed, orange, massive	Varied weathering, much digestion	Slight
6	Infill	External	Red brown, massive	Mixed sources	Moderate
1	Infill	Foundation trench infill	Clay, massive	Good condition, only small fragments gnawed	Slight
2	Infill	Foundation trench infill	Clay, massive	Good condition, only small fragments gnawed	Slight
3	Midden	Foundation trench infill	Some clay, massive	Weathering not severe, little digestion	Slight
4	Midden	Foundation trench infill	Some clay, massive	Weathering not severe, little digestion	Slight
7	Dump	Foundation trench infill	Brown, clay, massive	Variable weathering, much gnawing	Slight
45	Infill	Make-up	Brown, massive	Rather abraded, re-deposited	Very slight
55	Midden	External	Brown, clay, massive	Bone coherent, little exposure, single dump	Slight
54	Midden	House infill	Brown, clay ,massive	Some articulations, weathering slight	Very slight
8	Midden	Infill	Layered, brown	Un-weathered, articulations, mixed midden	Slight
51	Infill	Infill - basal layer dump	Massive	Non-cattle has little integrity	Slight
52	Infill	Bin fill, dump	Clay, massive	articulated unfused bone, in situ	Slight
53	Infill	Bin fill	Clay, massive	articulated unfused bone, in situ	Very slight
10	Infill	Off-site	Marl, massive	Rapidly buried, mixed, good condition	Slight
64	Midden	Off-site	Greyish, silty, ashy, fine lenses	Fairly rapidly buried, low integrity midden	Slight
47	Midden	Off-site	Greyish, silty, ashy, fine lenses	Rapid, exposed good preservation midden	Slight
50	Midden	Off-site	Greyish, silty, ashy, fine lenses	Rapid, exposed good preservation midden	Slight
65	Midden	Off-site	Greyish, silty, ashy, fine lenses	Rapid, exposed good preservation midden	Slight
66	Midden	Off-site	Greyish, silty, ashy ,fine lenses	Rapid, exposed good preservation midden	Slight

Appendix 10 cont.

Identification number				*Stratigraphic detail*			*Phasing Levels*			
Specimen	*Unit*	*Faunal*	*Year of excavation*	*Area*	*Space*	*Associated Building*	*Mellaart*	*Hodder (in process)*	*Textual re-phasing*	*Farid (pers. comm. 9.12.09)*
43	15820	F86	2007	TP		Near 4	Pre-I	TP Level		
44	15820	F88	2007	TP		Near 4	Pre-I	TP Level		
67	7898	F237	2004	TP		Above Neolithic roof	I	TP Level		
29	13098	F49	2006	TP	1307k	Burial edge	I	TP Level		
31	13570	F172	2007	TP	318	After 72	II	TP Level		
26	13079	F276	2006	TP		Below 62	Pre-II	TP Level		
27	13079	F290	2006	TP		Below 62	Pre-II	TP Level		
28	13079	F291	2006	TP		Below 62	Pre-II	TP Level		
12	7813	F416	2003	TP		Under 33,34	III-I	TP Level		
9	2600	F202	1997	South		Near 10 & surface		South. R	South. T	
32	14038	F31	2006	South	119	North of 10		South. R	South. T	
33	14059	F1	2006	South	119	North of 10		South. R	South. T	
59	14572	F76	2007	South	319	South of 44		South .Q	South. S	
77	16260	F443	2008	South	129	External 44		South .Q	South. S	
78	16260	F444	2008	South	129	External 44		South .Q	South. S	
60	16262	F102	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
57	16262	F100	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
68	16262	F103	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
58	16262	F65	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
56	16262	F64	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
62	16262	F66	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
63	16262	F108	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
61	16262	F99	2008	South	319	South of 44 near surface	IV - III	South .Q	South. S	
42	15728	F101	2007	South	319	South of 44 near base	IV - III	South. P	South. R	
70	15728	F102	2007	South	319	South of 44 near base	IV - III	South. P	South. R	

Appendix 11

Table of specimens showing contextual and stratigraphic details; those highlighted in grey show the chronological thread used in this thesis

Identification number				*Stratigraphic detail*				*Phasing Levels*		
Specimen	*Unit*	*Faunal*	*Year of excavation*	*Area*	*Space*	*Associated Building*	*Mellaart*	*Hodder (in process)*	*Textual re-phasing*	*Farid (pers. comm. 9.12.09)*
21	12456	F466	2006	IST	294		IV	IST IV		=South. Q/R
22	12456	F711	2006	IST	294		IV	IST IV		=South. Q/R
23	12456	F713	2006	IST	294		IV	IST IV		=South. Q/R
24	12456	X120	2006	IST	294		IV	IST IV		=South. Q/R
25	12456	X128	2006	IST	294		IV	IST IV		=South. Q/R
18	11862	F305	2005	IST	289	63	IV	IST IV		=South. Q/R
19	11897	F11	2005	IST	289	63	IV	IST IV		=South. Q/R
20	12456	F465	2006	IST	294		V - IV	IST IV		=South. Q/R
69	14916	F2	2007	4040	315	Under 70 & 71	V - IV	4040. F		=South. Q/R
40	14916	F3	2007	4040	315	Under 70 & 71	V - IV	4040. F		=South. Q/R
41	14916	F4	2007	4040	315	Under 70 & 71	V - IV	4040. F		=South. Q/R
16	10264	X52	2004	4040	227	Basal 58	IV - III	4040.G		=South. Q/R
36	14183	F11	2007	4040	279	In 61, after 64 abandoned	V	4040.G		=South. Q/R
37	14187	F49	2007	4040	279	In 61, after 64 abandoned	V	4040.G		=South. Q/R
34	14070	F1	2006	South	128	69				=South P/R
35	14071	F2	2006	South	128	69				=South P/R
73	17047	F751	2008	South	339	South of 56	V - IV		South. Q	
74	17047	F294	2008	South	339	South of 56	V - IV		South. Q	
75	17047	F379	2008	South	339	South of 56	V - IV		South. Q	
30	13370	X22	2006	South	299	South of 65	IV		South. Q	
71	16247	F3	2008	South	299,355	South of 65	IV		South. Q	
72	15743	F1220	2007	South	299,305	South of 65	IV		South. Q	
76	15743	F1219	2007	South	299,305	South of 65	IV		South. Q	
38	14800	F4	2007	South	257	53	V		South. P	
39	14807	F237	2007	South	261	East of 53	V		South. P	

Appendix11 cont.

Identification number				*Stratigraphic detail*			*Phasing Levels*			
Specimen	*Unit*	*Faunal*	*Year of excavation*	*Area*	*Space*	*Associated Building*	*Mellaart*	*Hodder (in process)*	*Textual re-phasing*	*Farid (pers. comm. 9.12.09)*
14	8624	F9	14	Bach	85	West of 3	VII -VI	Bach Levels		=South. P/Q
13	8178	F219	13	Bach	85	West of 3	VII -VI	Bach Levels		=South. P/Q
15	8632	F183	15	Bach	88	South of 3	VII -VI	Bach Levels		=South. P/Q
6	1315	F118	6	North	73	Between 1 & E.30	VII - V	Bach Levels		=South. P/Q
1	1023	F201	1	South	105	E.VII	VII	South. M		
2	1023	F202	2	South	105	E.VII	VII	South. M		
3	1038	F75	3	South	105		VII	South. M		
4	1038	F76	4	South	105		VII	South. M		
7	1511	F283	7	South	105		VII	South. M		
45	2000	F29	45	South	109	M19 Foundation	VII	South. M		
55	3740	F389	55	South	115	Below 40	VIII	South. L		
54	4121	F1833	54	South	115, near top		VIII	South. L		
8	1629	F133	1996	South	116	2	IX	South. K		
51	1873	F532	1997	South	117	2, post abandonment	IX	South. K		
52	1889	F183	1997	South	117	2	IX	South. K		
53	1889	F184	1997	South	117	2	IX	South. K		
10	6031	F81	1999	KOPAL	Near base		Pre-XII - XII	KOPAL		
64	4838	F627	1999	South	181 near top		Pre-XII.A	South. G		
47	5290	F2635	1999	South	184 near base		Pre-XII.B	South. G		
50	5290	F2608	1999	South	183 near base		Pre-XII.B	South. G		
65	5290	F2630	1999	South	182 near base		Pre-XII.B	South. G		
66	5290	F2631	1999	South	181 near base		Pre-XII.B	South. G		

Appendix 11 cont.

Specimen	*Security of deposition*	*Chronological order*	*Chronological group*	*Area groups*	*Building-type groups*
43	***	72	6	2	2
44	***	71	6	2	2
67	***	70	6	2	2
29	*	69	6	2	
31	***	68	6	2	
26	*	67	6	2	
27	*	66	6	2	
28	*	65	6	2	
12	*	64	6	2	
9	**	63	6	1	
32	***	62	6	1	1
33	***	61	6	1	
59	***	60	5	1	1
77	***	59	5	1	1
78	***	58	5	1	1
60	***	57	5	1	1
57	***	56	5	1	1
68	***	55	5	1	1
58	***	54	5	1	1
56	***	53	5	1	1
62	***	52	5	1	1
63	***	51	5	1	1
61	***	50	5	1	1
42	***	49	5	1	1
70	***	48	5	1	1
21	***	47	4	2	
22	***	46	4	2	
23	***	45	4	2	
24	***	44	4	2	
25	***	43	4	2	
18	**	42	4	2	
19	*	41	4	2	
20	***	40	4	2	
69	***	39	4	2	2
40	***	38	4	2	2
41	***	37	4	2	2
16	***	36	4	2	
36	***	35	4	2	2
37	***	34	4	2	2
34	*	33	3	1	
35	***	32	3	1	
73	***	31	3	1	1
74	***	30	3	1	1
75	***	29	3	1	1
30	*	28	3	1	
71	*	27	3	1	
72	***	26	3	1	1
76	***	25	3	1	1
38	***	24	3	1	
39	***	23	3	1	1

Appendix 12

All specimens, showing depositional security, chronological sequence and group allocation

Specimen	*Security of deposition*	*Chronological order*	*Chronological groups*	*Area groups*	*Building- type groups*
14	***	22	2	2	2
13	***	21	2	2	2
15	*	20	2	2	2
6	*	19	2	2	
1	**	18	2	1	
2	**	17	2	1	1
3	**	16	2	1	2
4	**	15	2	1	2
7	*	14	2	1	
45	*	13	2	1	
55	**	12	1	1	2
54	**	11	1	1	2
8	***	10	1	1	2
51	*	9	1	1	
52	***	8	1	1	
53	***	7	1	1	
10	***	6	1	2	
64	***	5	1	1	
47	***	4	1	1	
50	***	3	1	1	
65	***	2	1	1	
66	***	1	1	1	

Area groups 1 South Areas
2 Other Areas

Building-type groups 1 Long-lived sequence
2. Short-lived houses

Appendix 12 cont.

Appendix13
Sample preparation and laboratory protocols

Isotope analytical procedures

All teeth were removed from their mandibles. The Bozdağ reference collection was not analysed. Crown heights were measured on the buccal side of the mesial cusp, from the occlusal surface to the cervix (Klein *et al.* 1981).

Samples were prepared for Elemental Analyser Isotope Reading Mass Spectrometry (EA-IRMS), designed to measure isotopic composition at low enrichment and natural abundance level. As the process of enamel formation is complex, alternative methods which aim for higher precision, such as micro-laser ablation (Sharp & Cerling 1996), were not considered an advantage.

Preparation protocol followed Balasse *et al.* (2002, 920). All teeth were cleaned with an abrasive tungsten drill bit and examined for damage and post-excavation re-gluing. Throughout sample preparation, nitrile latex-free gloves were worn, and de-ionized water was used to clean the equipment, preparation surfaces and the teeth. Powdered 10-15mg samples of tooth enamel were drilled at low speed to avoid any effects arising from high temperature or melting (Wiedmann *et al.* 1999). Where possible, eight bands were sampled along the length of the meso-buccal pillar in parallel *c.* 1mm bands. Care was taken to avoid dentine contamination.

Samples were then prepared for analysis of the inorganic carbonate component. They were immersed in 2-3% NaOCl for 24 hours to remove organic contamination, before being centrifuged at 12,5000rpm for five minutes, and the residue washed in de-ionized water three times. To remove any diagenetic carbonates the residues were next immersed in 0.1M

acetic acid, at 0.1ml solution per 0.1mg sample, for four hours, and again centrifuged and washed three times, before drying for two days. Aliquots were then measured for IRMS analysis of the oxygen isotope values in the enamel inorganic carbonate.

The requirement to run a pilot study, to have a suitable sample size analysed in order to upgrade from an MPhil to a PhD, and the decision by the National Environment Research Council (NERC) to limit sample size, resulted in more than one laboratory being used. Whilst this might appear unsatisfactory, the rigorous procedures followed by each laboratory allow explicit assessment of reproducibility to be made. Details of analytic procedure are summarised below, and the procedure in one laboratory is discussed in detail in Henton *et al.* (2010).

In brief, sample aliquots are subjected to acid digest, which releases representative carbon dioxide for mass spectrometer analysis of the $\delta^{18}O$ values. Analytical precision is tested by bracketing the samples within international and laboratory standards with known $\delta^{18}O$ values. Any drift may then be corrected and, if necessary, sample readings re-calibrated (Meier-Augenstein 2007, 35).

	Queens University Belfast	*NIGL*	*Stanford School of Earth Sciences*	*Scottish Crop Research Institute*
Sample size (mg)	4	0.9-1.1	4-4.5	2
International Standard	NBS-19	NBS-19 calcite KCM	Coral	NBS-19 & LSVEC
Laboratory standard	Sodium bicarbonate A	Mastodon enamel	A less carbonate rich standard	Sodium bicarbonate A
	Sodium bicarbonate B			Sodium bicarbonate B
Acid	Absolute sulphuric acid	Anhydrous phosphoric acid	Anhydrous phosphoric acid	
Mass spectrometer	Gas isotope measuring AP2003	GV IsoPrime dual inlet	Thermo Finnigan Delta^{PLUS} X1	AP 2003
Sub- samples	3	3	3	3
Typical Precision	<0.18‰	<0.04‰	<0.2‰	<0.45‰

Diagenesis of the inorganic carbonate component of tooth enamel was tested by comparison to the phosphate component, before it was considered safe to proceed with analysis of the carbonate component. Sample preparation for phosphate analysis is as follows. Powdered enamel samples were agitated in 0.125M sodium hypochlorite solution for 24 hours, and then centrifuged. The residue was washed in 2ml of 2M hydrofluoric acid for a further 24 hours and again centrifuged. 3ml of 2M potassium hydroxide was added to the supernatant (apatite solution). The washed residue was added, the solution made up to 200ml with de-ionized water, and 15ml of buffered amine solution added. This was heated to 70°C for three hours before cooling. Resultant crystals of silver phosphate (apatite precipitate) were washed, dried, and 0.2mg weighed for individual analysis.

Dental microwear analytical procedures

For all teeth, dental microwear analysis was completed before samples were prepared for isotope analysis; the former procedure is non-invasive and the latter destructive. The procedure follows Mainland (*all references*). The occlusal surface of the paraconid cusp was thoroughly cleaned with de-ionised water and the meso-buccal quadrant of the infundibular enamel band examined for non-dietary abrasion under low magnification.

Three impressions of each suitable specimen were made, using Coltène President Light-body putty. The first was used to remove remaining contamination and then discarded, the second two were retained. Maintaining the correct orientation, a cast was made using Epo-Tek 301, a 2-part epoxy system. Each cast was then mounted on a stub.

Each stub was then gold-coated in an Emscope Gold Coater, before being placed in the chamber of a Hitachi S–3400N scanning electron microscope (SEM). Using secondary

electrons under high vacuum, constant settings were established. The acceleration voltage of the beam was set to 10.00kV, and a high probe current was used to provide a good depth of field at low magnification.

The correct section of the infundibular band was aligned so that it was parallel to the left-hand edge of the screen, and inspected under different magnifications. Three areas with good, representative microwear were captured at x500 resolution, and saved as Bitmap files. This was repeated for the second cast made from each tooth, thus six images were captured for each.

The six images were assessed, and the most representative example was imported into Ungar's (2002) image analysis software (Microware 4.02). The dimensions and orientation of each microwear feature, in a surface area of 0.0404mm^2, were marked and quantified onto an overlay, and then stored as raw data to be exported into an Excel 4 worksheet. Pit features were recorded down to one micron, curved striations were measured in a series of straight lengths, palimpsests were ignored and only the most recent features recorded.

In addition a qualitative assessment of each image was made, noting the condition of the enamel surface; truncation or curvatures in any features; and reduction in the area of quantification due to irregularities. Adjustments were made for area reduction, measurements of curved features were amalgamated and their orientation averaged, and truncated features noted separately in the database.

The data from all teeth was then imported into an SPSS database using syntax constructed for left and right hand teeth (Mainland *all references*). The syntaxes generate tables and descriptive statistics based on the continuous, dichotomous and polychotomous categories established by Solounias and Hayek (1993).

Food and dung analytical procedures

Food and dung samples were dried and then weighed, before burning off the organic fraction by loss-on-ignition, at 550°C for two hours. The remaining inorganic fraction was reweighed. To separate the soil and phytolith components of the inorganic fraction, 3ml sodium polytungstate (SPT) was added to the inorganic fraction. After centrifuging for ten minutes at 800rpm the lighter phytolith fraction was floated off. The phytolith fraction was centrifuged for five minutes at 2000rpm and then washed. After repeating three times, the phytolith pellet was dried before being weighed.

Specimen	*Enamel fraction*	*$\delta^{18}O_{VSMOW}$ results for each sample band* *Carbonate fraction (shaded grey)* *Phosphate fraction (unshaded)*			
		1	*2*	*3*	*4*
50	Carbonate	27.0	28.6	32.3	34.5
	Phosphate	17.1	19.7	23.2	25.3
54	Carbonate	28.9	30.6	30.8	29.7
	Phosphate	18.0	19.3	21.4	20.9

Appendix 14
Results of tests on possible diagenesis of oxygen isotopes in the carbonate and phosphate fractions of archaeological teeth

Sample	*Payne age*	*Crown height (mm)*	*Distance of sampling bands from root/enamel junction (shaded grey) $\delta^{18}O_{VSMOW}$ results for each sample (unshaded)*								
			9	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
66	2-3y	30		26.2	22.7	19.7	16.2	12.7	9.6	5.5	2.1
				26.7	25.0	24.6	23.8	26.7	26.3	28.1	29.7
65	4-6y	23.8			22.0	19.0	15.3	11.3	8.9	5.6	2.1
					23.5	22.7	25.4	27.4	28.9	27.0	25.1
50	4-6y	31.4			27.5	23.5	19.4	15.3	10.4	6.6	2.5
					26.0	27.0	28.6	32.3	34.5	35.0	31.7
47	1-2y	28.6			26.0	20.8	16.7	10.8	6.5	4.3	1.6
					29.2	25.1	26.5	28.3	33.2	34.2	34.1
64	4-6y	20.7				20.4	17.5	13.0	9.1	5.4	2.5
						25.2	24.3	27.0	29.4	28.9	27.7
10	1-2y	28.6		25.1	22.0	18.2	15.9	12.8	10.0	7.1	3.5
				24.6	25.0	24.7	23.7	25.7	25.1	28.3	29.8
53	3-4y	24.1			22.6	19.3	15.4	12.5	8.1	4.8	1.1
					27.2	28.0	29.0	32.6	29.8	31.4	25.7
52	4-6y	25.3			23.6	19.5	16.3	13.1	10.2	6.7	3.0
					30.2	27.2	26.0	27.4	26.9	35.5	35.4
51	4-6y	20.2			17.0	16.4	13.7	11.4	8.2	4.3	1.6
					26.1	30.4	29.6	31.9	34.1	33.8	30.4
8	3-4y	27.4		23.7	21.0	19.0	15.4	12.2	9.6	6.8	3.5
				25.3	25.3	27.6	28.9	27.4	27.1	25.6	23.6
54	1-2y	29.4	27.7	24.8	21.6	18.5	16.1	13.2	10.3	7.5	2.2
			26.7	28.6	28.9	30.6	30.8	29.7	33.3	28.2	32.2
45	1-2y	31.7		27.9	24.0	20.1	16.2	12.8	8.9	4.9	2.1
				30.4	25.1	23.7	22.6	28.2	28.5	29.2	26.9
7	2-3y	33.3		29.2	25.8	22.5	17.6	13.5	10.1	6.1	2.7
				24.4	23.1	24.0	20.2	25.9	27.8	29.5	29.0
4	2-3y	32.8		30.1	24.2	20.2	17.3	12.2	8.9	5.5	2.4
				24.5	23.4	25.4	24.6	28.3	28.7	30.4	29.4
3	2-3y	28.5		26.8	22.6	19.0	15.5	11.7	7.8	4.0	1.1
				32.3	28.2	23.9	23.0	25.7	29.0	31.1	33.6
2	2-3y	27.8		25.1	21.9	18.5	14.8	11.5	7.6	4.6	1.5
				29.7	27.2	25.6	24.5	24.8	27.6	30.1	31.1
1	2-3y	35		29.5	25.0	21.2	17.4	13.8	10.6	6.7	2.5
				28.8	25.7	25.9	24.2	25.4	25.9	27.0	28.4
13	3-4y	26.7			25.1	18.9	17.3	13.6	10.0	7.7	3.3
					24.8	25.8	26.7	26.6	27.1	27.0	24.3
14	4-6y	23.4				22.0	13.5	10.3	7.1	4.5	1.7
						25.3	28.5	29.4	30.5	29.7	29.2
39	4-6y	23.5					20.0	16.9	13.8	10.5	3.5
							26.6	30.0	31.4	33.8	30.1
38	1-2y	27.2		25.4	22.5	19.5	17.2	14.8	11.6	7.0	3.7
				23.9	21.9	22.2	25.2	28.0	29.9	30.5	28.7
71	4-6y	23.3			19.6	16.9	14.9	12.9	8.8	4.9	1.4
					24.3	25.9	26.0	27.9	32.0	30.7	29.0
30	3-4y	21.2			19.5	17.1	14.2	11.6	8.7	6.2	3.1
					28.5	27.9	27.0	26.4	26.6	27.7	25.5
75	4-6y	24.9		24.1	22.4	18.2	14.4	11.7	8.7	5.6	2.9
				24.4	24.6	26.8	27.2	26.8	27.2	23.5	23.5
74	2-3y	34.2		31.5	28.9	24.6	15.4	13.9	11.0	9.8	6.0
				25.3	23.3	23.5	25.1	25.6	26.2	25.9	28.1
73	3-4y	27.4		25.0	21.8	17.8	14.4	11.0	8.5	5.7	2.1
				27.0	25.9	28.9	23.9	31.5	31.8	31.3	29.8
35	4-6y	21.1				18.5	15.1	13.3	9.8	6.1	2.5
						26.0	27.5	27.3	31.3	31.6	34.3
34	3-4y	26		23.3	20.0	16.7	14.9	12.7	10.4	7.9	4.4
				24.7	23.9	26.6	27.9	29.0	32.2	32.1	31.2
37	3-4y	21.1				18.2	15.3	11.7	7.9	4.3	1.4
						24.1	26.0	28.8	29.7	29.2	25.5
36	4-6y	27.5		23.0	20.6	16.9	14.4	11.5	7.7	5.1	2.1
				23.9	25.8	27.1	28.8	30.0	30.1	29.8	27.3
41	4-6y	29.4		25.5	21.4	19.3	16.1	12.9	8.2	5.0	2.2
				25.3	25.3	27.7	25.9	27.5	30.9	30.6	30.8
40	2-3y	31.3		28.1	24.5	20.9	17.0	12.9	8.9	5.8	1.4
				29.0	27.2	23.9	21.2	21.6	25.5	31.0	30.1

Appendix15

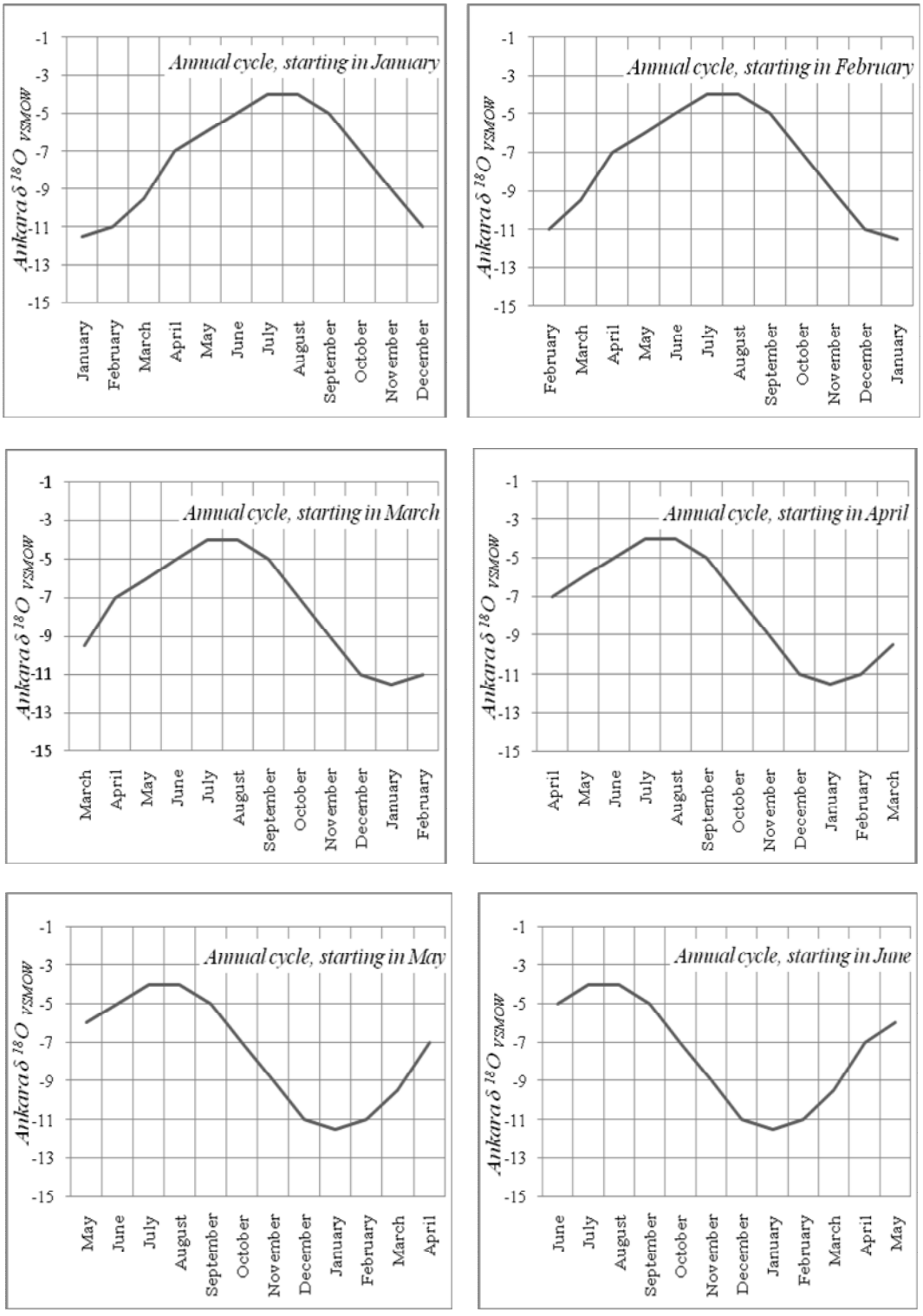
Table of oxygen isotope results for all archaeological teeth (58 specimens)

Sample	*Payne age*	*Crown height (mm)*	*Distance of sampling bands from root/enamel junction (shaded grey) $\delta^{18}O_{VSMOW}$ results for each sample (unshaded)*								
			9	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
69	3-4y	27.1		26.0	22.1	20.1	17.6	12.1	9.3	5.3	1.4
				28.1	27.0	26.4	28.8	28.1	26.7	25.6	26.4
20	3-4y	27.1		25.9	23.4	20.3	16.5	13.5	10.0	7.0	3.4
				25.2	27.4	29.6	31.0	30.7	30.5	28.6	24.6
18	4-6y	24.8					16.7	13.4	10.1	6.4	3.1
							30.9	31.1	30.7	26.8	22.6
24	3-4y	27.7		26.0	22.7	19.7	16.6	12.5	9.1	5.8	2.0
				24.0	25.7	26.5	29.4	31.7	32.4	31.7	27.2
23	4-6y	16.3					14.9	12.3	8.4	5.2	2.0
							26.9	27.3	24.5	25.4	23.9
22	4-6y	18.5					16.6	13.2	9.1	5.4	3.5
							30.7	33.4	34.5	34.0	30.8
21	6-8y	26.1			25.9	22.5	18.9	15.3	12.1	6.1	2.5
					24.6	23.9	25.6	25.4	29.5	30.2	29.7
70	6-8y	13.6					13.5	10.7	7.5	5.1	1.8
							26.3	28.3	26.6	25.0	25.1
42	3-4y	23		21.8	19.4	17.5	14.1	11.1	7.7	4.9	1.9
				23.8	25.7	27.0	29.2	30.2	27.4	28.0	26.6
61	4-6y	19.9				17.4	15.4	12.4	9.1	5.9	1.9
						24.4	26.0	27.2	29.5	27.9	27.2
62	1-2y	30		27.2	24.0	20.1	16.2	13.2	9.4	6.2	2.8
				25.9	25.2	26.7	27.2	29.0	30.3	29.7	29.7
56	4-6y	16.8				14.8	12.4	10.5	7.8	4.9	2.5
						26.9	28.2	29.1	29.6	27.0	25.2
58	3-4y	23.5			22.0	18.8	15.2	11.1	8.9	5.9	1.9
					25.7	27.8	29.5	27.7	26.4	28.1	24.7
60	4-6y	34.5		29.5	26.0	22.5	18.5	15.0	11.1	7.0	3.5
				26.7	25.7	26.4	24.9	26.6	26.9	23.5	24.0
59	4-6y	13.3				12.4	10.3	8.4	6.1	4.2	1.4
						28.7	28.5	25.8	24.6	25.1	27.4
32	4-6y	22.2				18.8	14.2	12.1	9.0	5.8	2.4
						23.3	22.1	24.6	26.1	26.5	24.2
9	2-3y	31.7		29.8	26.0	21.2	16.7	13.0	9.5	5.9	2.2
				29.6	27.5	26.5	27.2	29.2	31.0	32.2	31.2
12	2-3y	29.4		26.8	24.3	22.6	19.7	15.3	10.3	6.9	4.4
				27.3	26.5	23.8	22.0	23.7	28.4	31.5	31.7
28	1-2y	28.4			24.3	20.4	17.8	14.1	11.3	5.9	3.2
					25.4	23.4	22.1	22.5	24.3	28.7	30.6
27	2-3y	28.5			24.5	21.8	17.8	15.1	12.8	6.9	3.1
					26.3	22.9	20.6	22.3	27.2	32.5	33.4
26	2-3y	32		29.4	25.9	22.7	18.8	15.2	12.0	7.9	3.7
				25.4	23.5	21.9	20.9	22.5	25.3	29.8	31.0
31	4-6y	27.2		25.0	20.0	16.9	14.6	11.3	8.5	5.9	2.2
				22.9	23.8	26.6	27.7	29.4	29.5	29.2	24.9
29	4-6y	19.3				19.1	15.7	11.1	9.1	5.2	2.0
						26.0	25.4	26.6	28.2	26.8	25.8
67	1-2y	30		27.2	23.0	19.1	16.5	13.8	10.6	5.4	1.7
				24.4	23.8	22.8	26.9	25.0	26.5	26.3	25.6
44	3-4y	29.5		27.6	24.1	21.6	17.3	14.3	10.7	7.6	2.7
				23.9	22.5	21.7	24.2	29.9	29.4	29.6	26.1
43	4-6y	25.7		25.1	21.6	17.4	14.9	11.5	8.1	5.2	2.8
				22.6	23.8	24.8	26.0	30.6	30.6	28.3	26.7

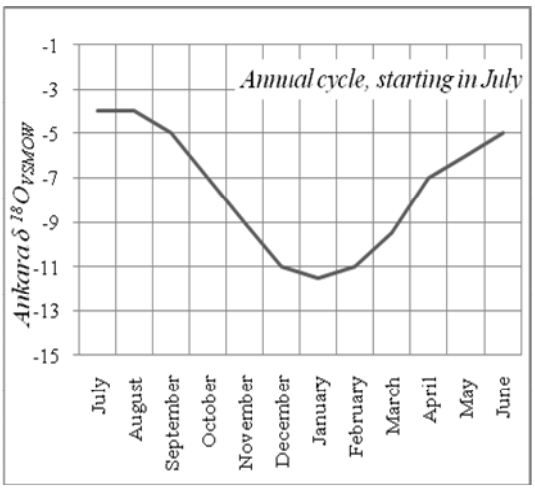
Appendix15 cont.

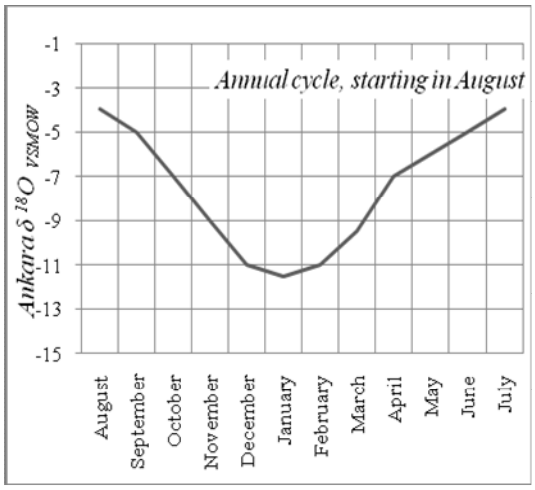
Sample	*Crown height (mm)*	*Distance of sampling bands from root/enamel junction (shaded grey)* $\delta^{18}O_{VSMOW}$ *results for each sample (unshaded)*							
		8	*7*	*6*	*5*	*4*	*3*	*2*	*1*
101	23.5	22.4	19.3	16.3	13.4	10.6	7.5	4.4	1.7
		29.7	28.5	27.9	26.3	25.0	23.1	24.2	29.3
102	26.1	24.8	21.0	18.8	15.2	12.4	8.8	5.8	2.4
		28.6	29.0	26.5	24.7	23.5	28.4	29.0	30.7
106	32.8	30.0	24.8	21.4	18.7	15.1	12.1	9.0	5.3
		26.5	26.1	25.7	26.7	27.6	29.0	30.1	32.4
201	28.1		28.0	25.3	22.0	19.5	16.1	13.8	10.0
			29.6	28.1	27.1	26.4	24.9	23.9	23.2
202	24.6	23.5	21.0	18.6	15.0	12.6	8.9	4.7	1.2
		24.9	25.6	27.1	27.3	28.2	28.6	27.1	26.3
203	20.1		19.6	16.7	13.7	10.5	8.3	5.1	3.3
			26.6	26.2	26.5	24.8	24.8	24.8	25.4
301	22.5	20.5	17.7	15.6	12.2	9.7	6.9	5.2	2.4
		25.2	23.9	23.2	23.4	25.9	27.7	31.0	30.7
302	34.7	32.0	28.0	24.0	19.1	15.2	10.6	7.4	2.4
		26.8	24.6	23.5	23.1	26.8	30.7	30.3	27.9

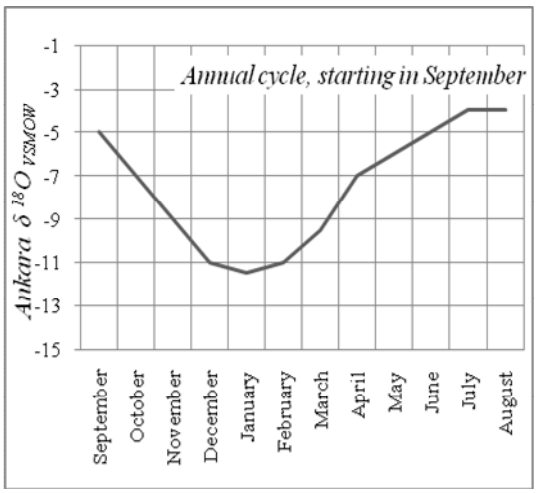
Appendix16
Table of oxygen isotope results for all modern teeth (10 specimens)

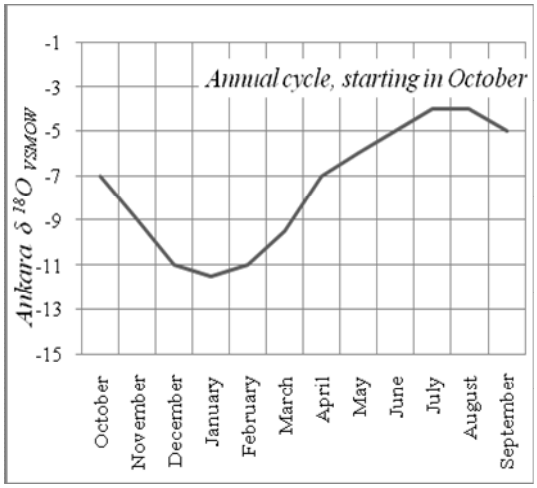


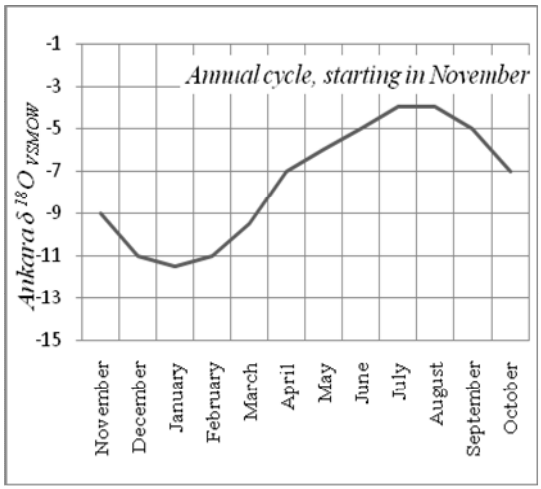
Appendix 17
Monthly GNIP data for Ankara, modelled to show annual cycles starting in different months

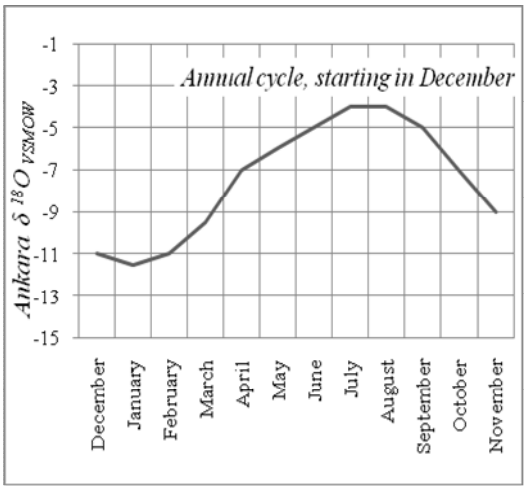












Appendix17 cont.

	Late winter	*Spring*		*Early summer*		*Autumn*	
	50% rising	*Entering cusp*	*On cusp*	*Leaving cusp*	*50% falling*	*Near trough*	*Not clear*
66		*					
65					*		
50				*			
47			*				
64				*			
10		*					
53							
52			*		*		
51							
8					*		
54							?
45				*			
7			*				
4			*				
3		*					
2		*					
1	*						
13					*		
14				*			
39					*		
38				*			
71					*		
30							?
75						*	
74	*						
73					*		
35		*					
34				*			
37					*		

	Late winter	*Spring*		*Early summer*		*Autumn*	
	50% rising	*Entering cusp*	*On cusp*	*Leaving cusp*	*50% falling*	*Near trough*	*Not clear*
36					*		
41			*				
40				*			
69							?
20					*		
18					*		
24					*		
23					*		
22					*		
21			*				
70						*	
42					*		
61					*		
62			*				
56					*		
58					*		
60							?
59	*						
32					*		
9				*			
12			*				
28		*					
27			*				
26			*				
31					*		
29					*		
67							?
44					*		
43					*		

Appendix 18
Interpretation of birth seasons for Çatalhöyük sheep, based on the curves of sequential oxygen isotope values shown in Fig.10.14

Phase	*Oxygen isotope evidence*		
	Sample (=less secure)*	*Birth*	*Movement in first year*
6	43	May	Plain,fan, sand-ridges, terraces
	44	May	Plain,fan, sand-ridges, terraces
	67	April	Movement to higher hills or karstic spring
	29*	May	Plain,fan, sand-ridges, terraces
	31	May	Plain,fan, sand-ridges, terraces
	26	April	Plain,fan, sand-ridges, terraces
	27	May	Plain,fan, sand-ridges, terraces
	28*	March	Plain,fan, sand-ridges, terraces
	12	April	Plain,fan, sand-ridges, terraces
	9	May	Plain,fan, sand-ridges, terraces
	32	May	Shaded valleys in terraces, lower hills
	33		
5	59	?	Shaded valleys in terraces, lower hills
	77		
	78		
	60	?	Movement to higher hills or karstic spring
	57		
	68		
	58	June	Plain,fan, sand-ridges, terraces
	56	May	Plain,fan, sand-ridges, terraces
	62	April	Plain,fan, sand-ridges, terraces
	63		
	61	May	Plain,fan, sand-ridges, terraces
	42	May	Plain,fan, sand-ridges, terraces
	70	?	Shaded valleys in terraces, lower hills
4	21	April	Plain,fan, sand-ridges, terraces
	22	May	Plain,fan, sand-ridges, terraces
	23	?	Movement to higher hills or karstic spring
	24	May	Plain,fan, sand-ridges, terraces
	25		
	18*	?	Plain,fan, sand-ridges, terraces
	19*		
	20	June	Plain,fan, sand-ridges, terraces
	69	?	Movement to higher hills or karstic spring
	40	May	Plain,fan, sand-ridges, terraces
	41	April	Plain,fan, sand-ridges, terraces
	16*		
	36	May	Plain,fan, sand-ridges, terraces
	37	June	Plain,fan, sand-ridges, terraces

Appendix 19
Interpreted movement during the first year for all archaeological sheep

Phase	*Oxygen isotope evidence*		
	Sample (=less secure)*	*Birth*	*Movement in first year*
3	34	May	Plain,fan, sand-ridges, terraces
	35*	March	Plain,fan, sand-ridges, terraces
	73	May	Plain,fan, sand-ridges, terraces
	74	March	Movement to higher hills or karstic spring
	75	?	Shaded valleys in terraces, lower hills
	30*	?	Shaded valleys in terraces, lower hills
	71	May	Plain,fan, sand-ridges, terraces
	72		
	76		
	38*	May	Plain,fan, sand-ridges, terraces
	39	May	Plain,fan, sand-ridges, terraces
2	14	May	Movement to higher hills or karstic spring
	13	May	Movement to higher hills or karstic spring
	15		
	6		
	1	March	Plain,fan, sand-ridges, terraces
	2	March	Plain,fan, sand-ridges, terraces
	3	March	Plain,fan, sand-ridges, terraces
	4	April	Plain,fan, sand-ridges, terraces
	7	April	Plain,fan, sand-ridges, terraces
	45	May	Plain,fan, sand-ridges, terraces
1b	55		
	54	April	Plain,fan, sand-ridges, terraces
	8	June	Plain,fan, sand-ridges, terraces
	51	May	Plain,fan, sand-ridges, terraces
	52*	April	Plain,fan, sand-ridges, terraces
	53*	June	Plain,fan, sand-ridges, terraces
1a	10	March	Plain,fan, sand-ridges, terraces
	64	May	Plain,fan, sand-ridges, terraces
	47	April	Plain,fan, sand-ridges, terraces
	50	May	Plain,fan, sand-ridges, terraces
	65	May	Shaded valleys in terraces, lower hills
	66	March	Plain,fan, sand-ridges, terraces

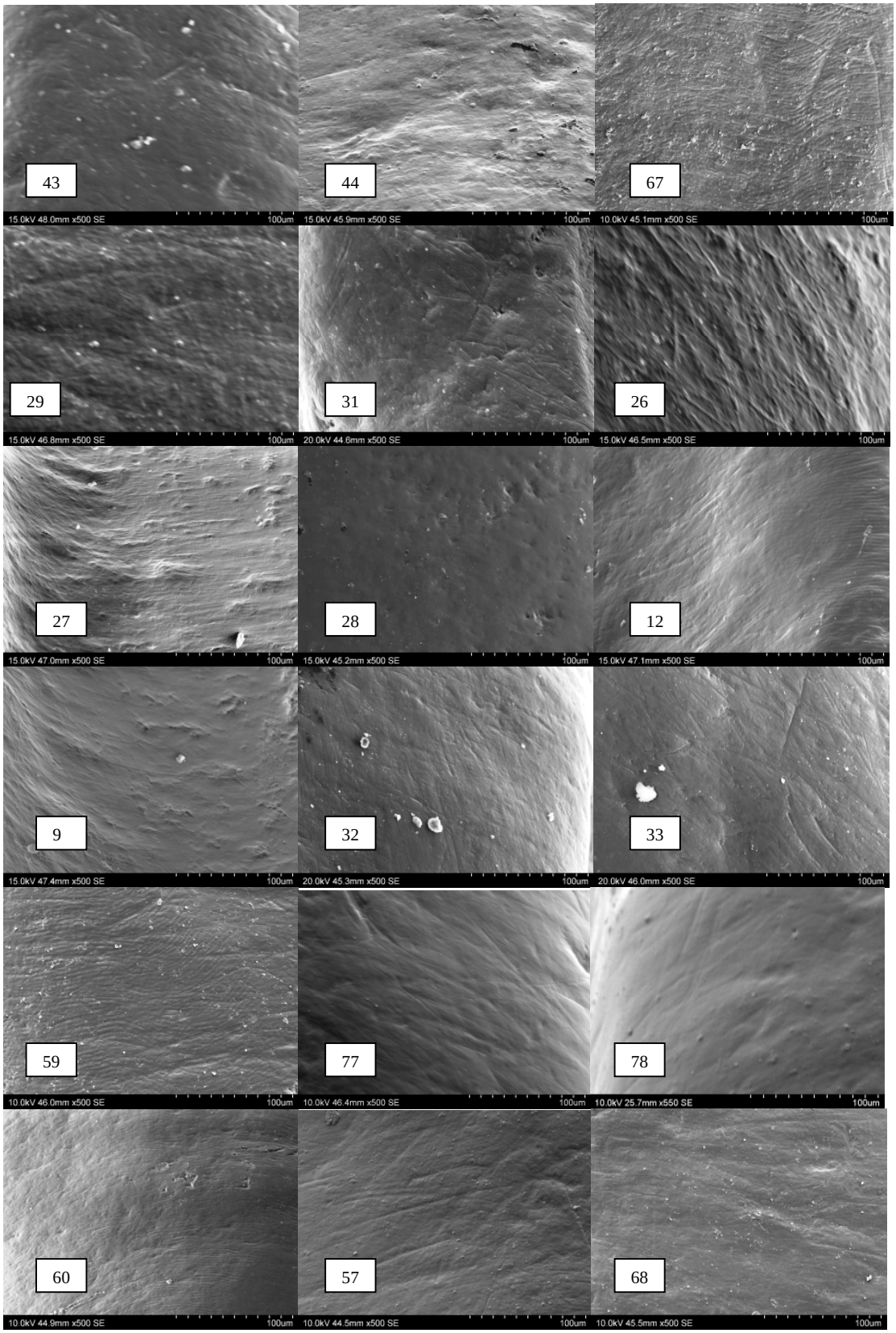
Appendix 19 cont.

Sample	*Description*		*By weight (gm)*							*By percentage*					
			Crucible	Crucible + inorganic	Complete sample	Organic fraction	Inorganic fraction	Phytolith fraction	Soil fraction	Organic %	Inorganic %	Phytolith % inorganic	Soil % inorganic	Phytolith % whole	Soil % whole
A1	Kızılkaya	Wheat & barley stubble August	5.698	5.814	0.527	0.411	0.116	0.101	0.015	77.989	22.011	87.069	12.931	19.165	2.846
A2			6.07	6.287	0.646	0.429	0.217	0.153	0.064	66.409	33.591	70.415	29.585	23.653	9.938
A3			5.782	5.871	0.491	0.402	0.089	0.057	0.032	81.874	18.126	63.820	36.180	11.568	6.558
C1	Küçükköy	Barley straw, winter	6.386	6.415	0.404	0.375	0.029	0.012	0.017	92.822	7.178	41.379	58.621	2.970	4.208
C2			4.98	5.034	0.677	0.623	0.054	0.018	0.036	92.024	7.976	33.333	66.667	2.659	5.318
C3			6.004	6.04	0.477	0.441	0.036	0.012	0.024	92.453	7.547	33.333	66.667	2.516	5.031
D1	Küçükköy	Legume straw, winter	5.213	5.253	0.526	0.486	0.04	0.013	0.027	92.395	7.605	32.500	67.500	2.471	5.133
D2			6.4	6.436	0.58	0.544	0.036	0.014	0.022	93.793	6.207	38.889	61.111	2.414	3.793
D3			5.868	5.914	0.65	0.604	0.046	0.017	0.029	92.923	7.077	36.957	63.043	2.615	4.462
E1	Bozdağ	Dry summer pasture, August	5.729	5.839	0.475	0.365	0.11	0.1	0.01	76.842	23.158	90.909	9.091	21.053	2.105
E2			4.982	5.022	0.7	0.66	0.04	0.021	0.019	94.286	5.714	52.500	47.500	3.000	2.714
E3			5.513	5.551	0.553	0.515	0.038	0.022	0.016	93.128	6.872	57.895	42.105	3.978	2.893
G1	Kızılkaya	Wheat straw winter	5.917	5.934	0.318	0.301	0.017	0.014	0.003	94.654	5.346	82.353	17.647	4.403	0.943
G2			5.65	5.68	0.466	0.436	0.03	0.022	0.008	93.562	6.438	73.333	26.667	4.721	1.717
G3			5.986	6.027	0.524	0.483	0.041	0.027	0.014	92.176	7.824	65.610	34.390	5.134	2.691
I1	Kızılkaya	Green pasture grass & forbs, June	5.856	5.931	0.976	0.901	0.075	0.011	0.064	92.316	7.684	14.667	85.333	1.127	6.557
I2			6.309	6.381	0.765	0.693	0.072	0.014	0.058	90.588	9.412	19.444	80.556	1.830	7.582
I3			5.274	5.388	1.246	1.132	0.114	0.015	0.099	90.851	9.149	13.158	86.842	1.204	7.945
K1	Kızılkaya	Green pasture grass & forbs, June	5.789	6.029	1.165	0.925	0.24	0.01	0.23	79.399	20.601	4.167	95.833	0.858	19.742
K2			5.657	5.864	1.292	1.085	0.207	0.13	0.077	83.978	16.022	62.802	37.198	10.062	5.960
K3			5.172	5.453	1.439	1.158	0.281	0.016	0.265	80.473	19.527	5.765	94.235	1.126	18.402
L1	Kızılkaya	Young green grass, April	5.115	5.387	2.578	2.306	0.272	0.083	0.189	89.449	10.551	30.515	69.485	3.220	7.331
L2			5.847	5.961	2.267	2.153	0.114	0.050	0.064	94.971	5.029	43.860	56.140	2.206	2.823
L3			5.929	6.336	2.754	2.347	0.407	0.036	0.371	85.221	14.779	8.894	91.106	1.314	13.464

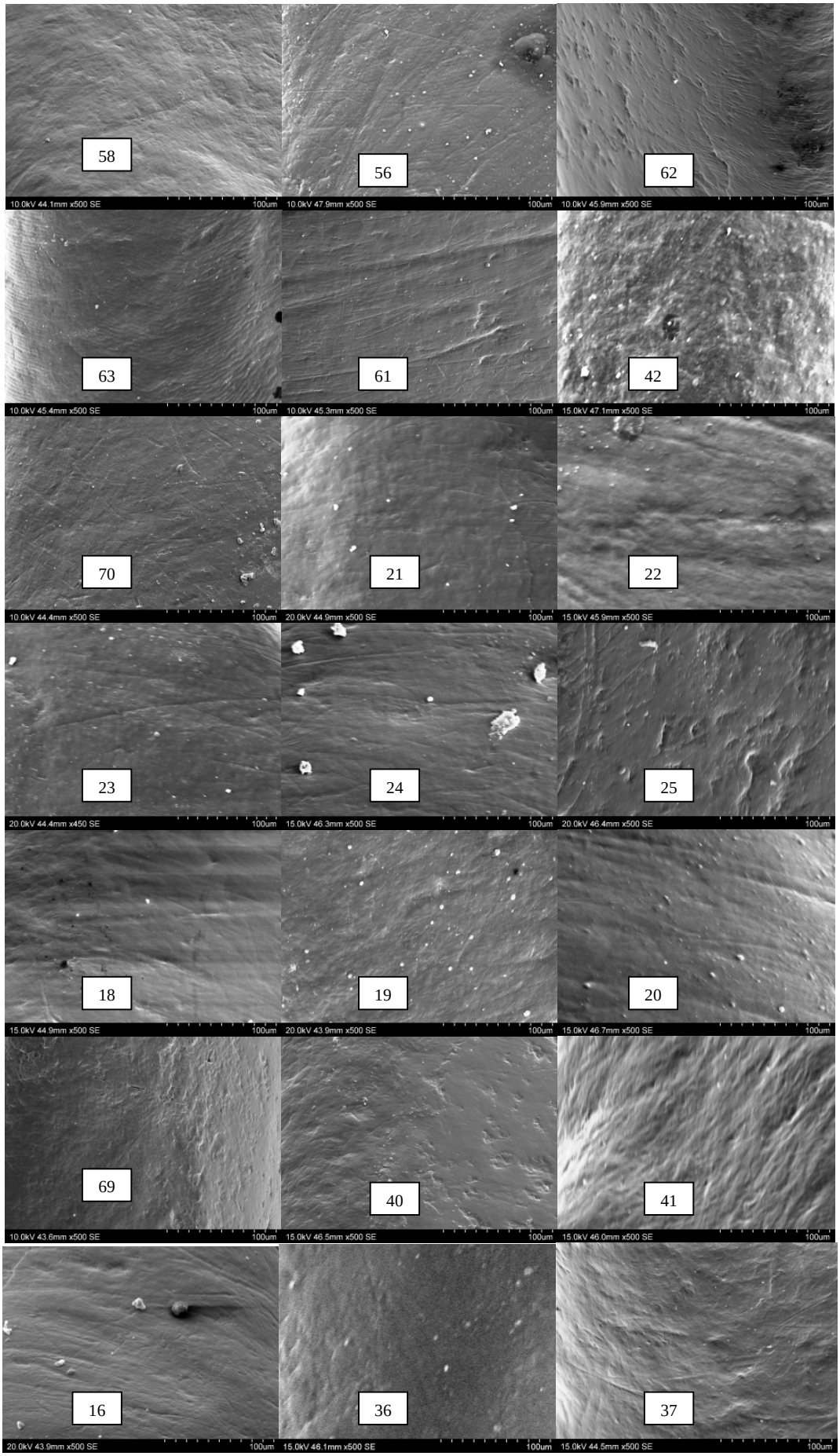
Appendix20
Results of component analyses of modern feeds

Modern tooth specimen	*Month of death*	*Food type*	*Age (Payne 1973)*	*All features*	*Pit %*	*Striation %*	*Pits*								*Striations*								
							Number	*Round*				*Oval*				Number	*Broad*				*Narrow*			
								Number	Length	Breadth	%	Number	Length	Breadth	%		Number	Length	Breadth	%	Number	Length	Breadth	%
103	May	Spring pasture	4-6y	124	65.3	347	81	49	7	48	60.5	32	9.9	3.5	39.5	43	18	11	19	41.9	25	17	1	58.1
410	Early June		3y	171	73.7	26.3	126	74	8	5.7	58.7	52	11	3.8	41.3	45	35	17	3	77.8	10	26	1.4	22.2
412	Early June		4y	158	59.5	40.5	94	50	12	8.4	53.2	44	14	5.3	46.8	64	34	13	1.8	53.1	30	20	1.2	46.9
415	Early July	Mid-summer pasture	5y	141	17.7	82.3	25	10	14	8.3	40.0	15	12	4.1	60	116	24	19	2.8	20.7	92	39	1.6	79.3
409	Early July		3y	66	37.9	62.1	25	20	9	6.8	80	5	14	5.1	20	41	21	21	3.2	51.2	20	33	1.5	48.8
101	Early July		4-6y	127	38.6	61.4	49	20	5	7.1	13	29	3.5	4.4	85	78	34	3	91.8	62	44	2	8.2	38
102	Early July		4-6y	138	42.8	57.3	59	16	6	4.4	27.1	43	7.2	2.5	72.9	79	47	10	1.7	59.5	32	24	1.4	40.5
301	Late August	Late pasture	4-8y	106	189	81.1	20	15	7	5	75	5	7.5	3	25	86	12	12	19	14	74	30	1.2	86.1
413	October		5y	156	24.4	75.6	38	23	6	5.1	60.5	15	11	3	39.5	118	35	16	2.2	29.7	83	28	13	70.3
106	Early December		1-2y	34	20.6	79.4	7	4	11	7.3	57.1	3	7.8	3.5	42.9	27	4	21	2.8	14.8	23	38	1.4	85.2
104	June	Cereal stubble	6-8y	96	28.1	71.9	27	19	9	6.6	70.4	8	12	5	29.6	69	6	18	2.6	8.7	63	27	1	91.3

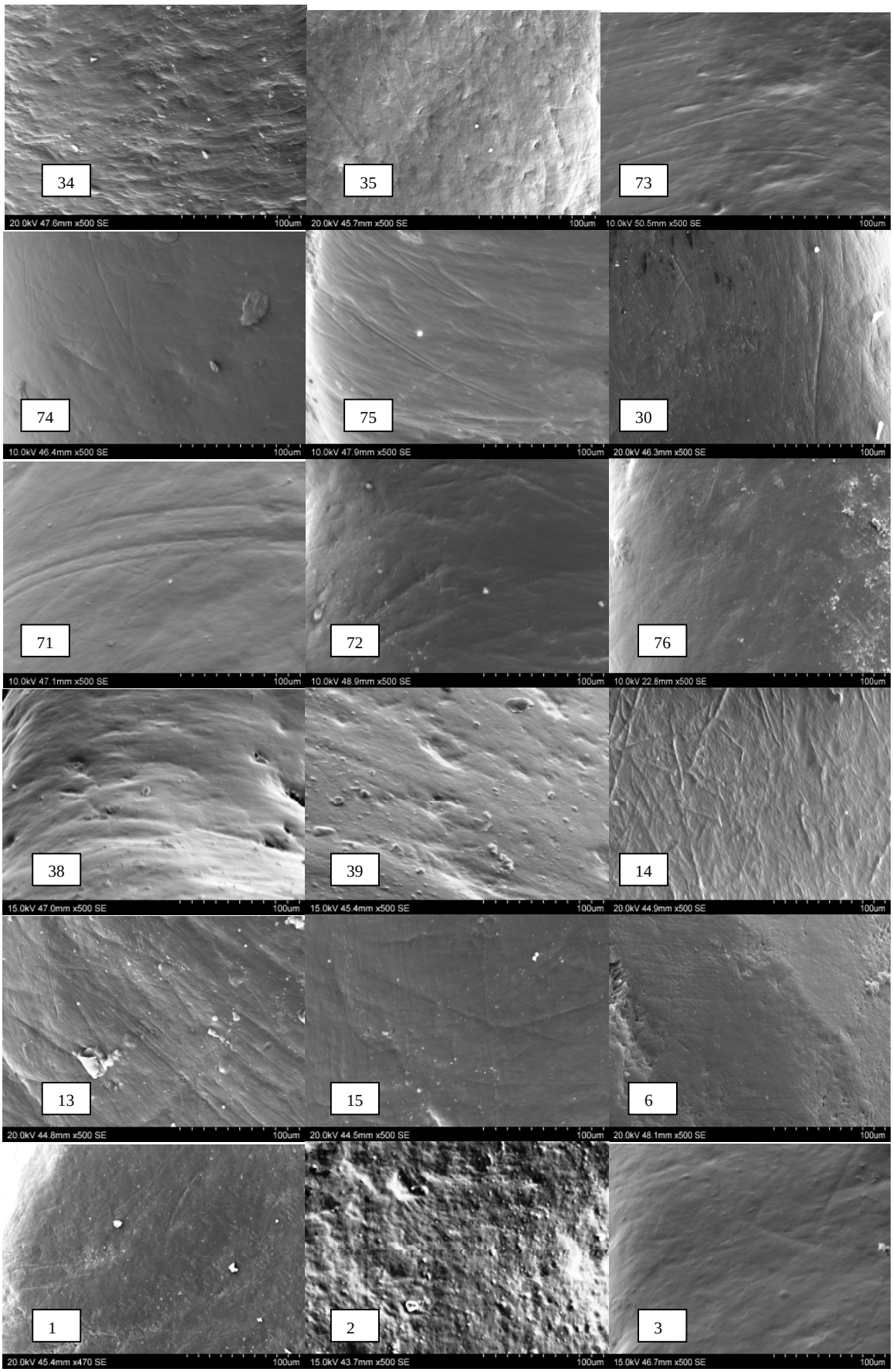
Appendix 21
Results of dental microwear analysis in modern specimens



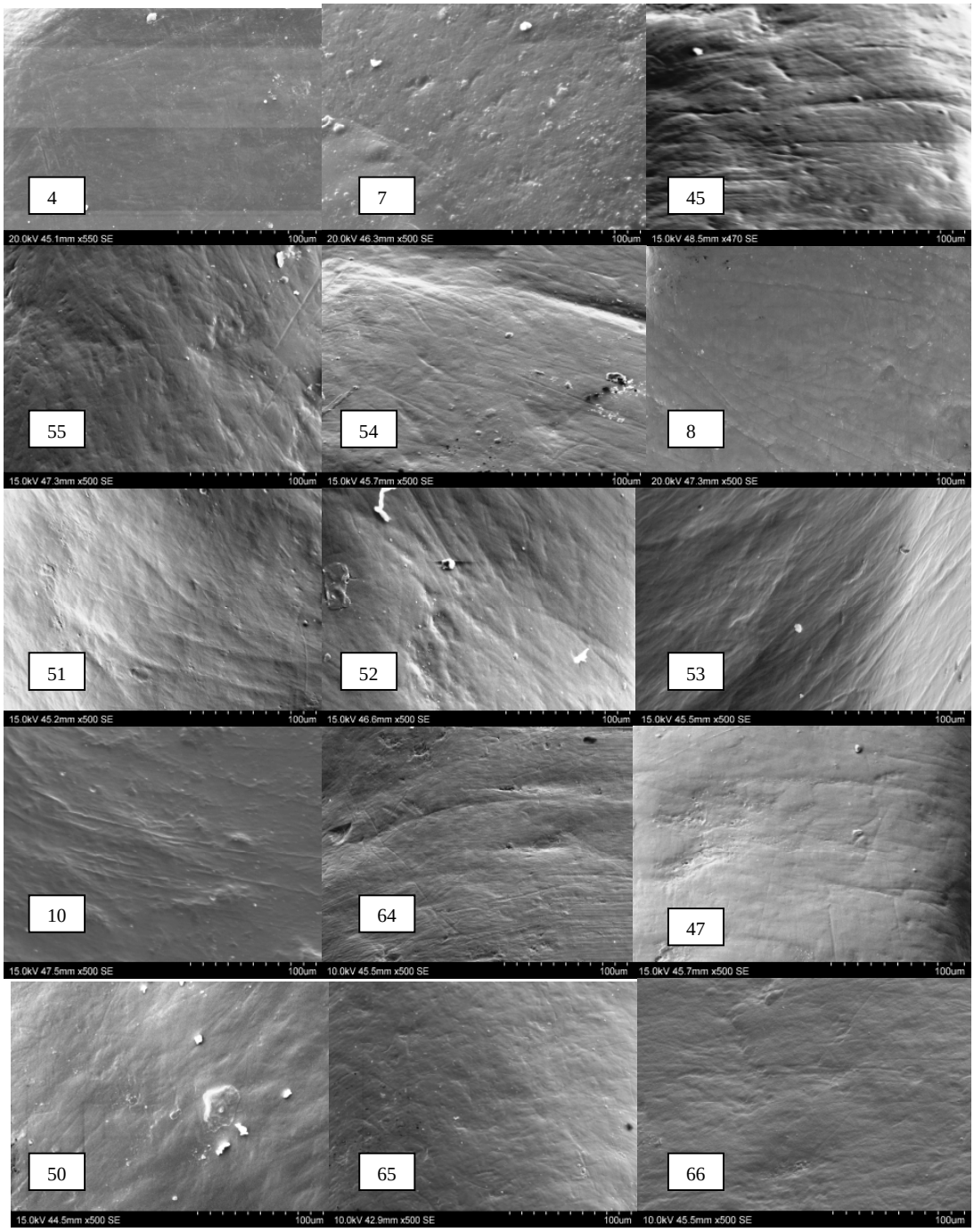
Appendix 22
SEM images (x500) showing the area of wear captured on the surface of all teeth, and used in dental microwear analysis – archaeological teeth



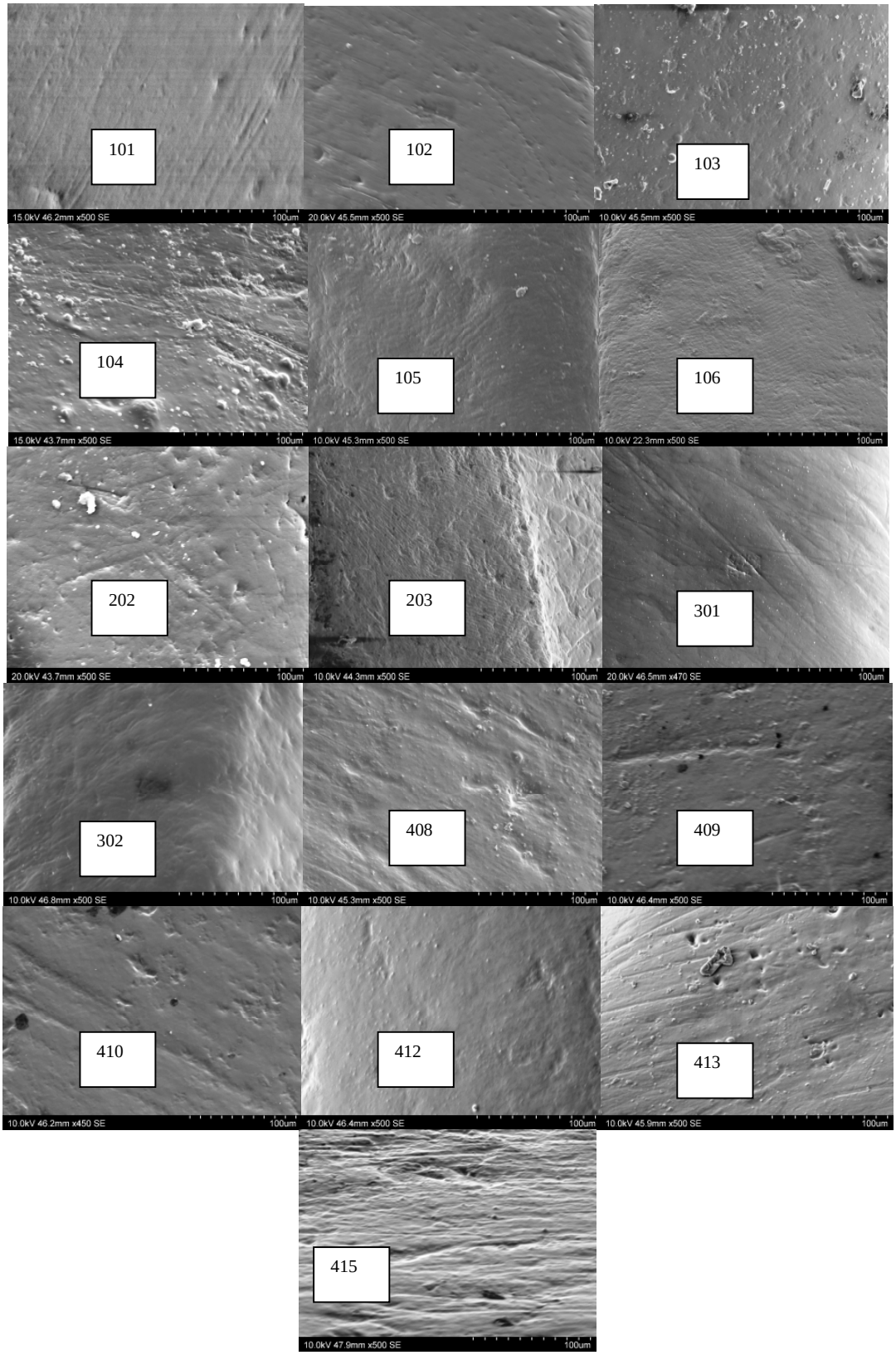
Appendix 22 cont.
Archaeological teeth



Appendix 22 cont.
Archaeological teeth



Appendix 22 cont.
Archaeological teeth



Appendix 22 cont.
Modern teeth

Solounias et al. 2000 *SEM x500*	Sample size	(0.0404mm^2)*			per mm^2			%
		All features	Pits	Striations	All features	Pits	Striations	Pits
Browsers								
Alces alces nearctic moose	9	64	43	21	1584.16	1064.36	519.80	67.19
Litocranius walleri gerenuk	24	40.8	27	13.8	1009.90	668.32	341.58	66.18
Cephalophus dorsalis bay duiker	21	48.3	23	25.3	1195.54	569.31	626.24	47.62
Boocercus euryceros bongo	15	35.1	19.6	15.5	868.81	485.15	383.66	55.84
Tragelaphus imberbis lesser kudu	21	38.1	20.5	17.6	943.07	507.43	435.64	53.81
Cephalophus niger black duiker	7	40.1	20	20.1	992.57	495.05	497.52	49.88
Tragelaphus strapsiceros greater kudu	11	38.4	16.5	21.9	950.50	408.42	542.08	42.97
Okapia johnstoni okapi	14	40.1	16.2	23.9	992.57	400.99	591.58	40.40
Cephalophus silvicultor yellow backed duiker	15	38.1	10.5	27.6	943.07	259.90	683.17	27.56
Giraffa camelopardalis giraffe	19	17.9	4.1	13.8	443.07	101.49	341.58	22.91
Grazers								
Kobus ellepsiprymnus common African waterbuck	17	68.2	26.3	41.9	1688.12	650.99	1037.13	38.56
Connochaetes tarinus wildebeest	26	53.4	10.2	43.2	1321.78	252.48	1069.31	19.10
Tetracerus quadricornis fourhorned antelope	6	51.4	9.7	41.7	1272.28	240.10	1032.18	18.87
Bison bison American plains bison	19	69.2	14.6	54.6	1712.87	361.39	1351.49	21.10
Hippotragus niger sable antelope	4	61.2	6.0	55.2	1514.85	148.51	1366.34	9.80
Axis axis chital	18	57.1	3.3	53.8	1413.37	81.68	1331.68	5.78
Cervus duvauceli barashingha	5	60.8	3.0	57.8	1504.95	74.26	1430.69	4.93
Mountain grazer								
Ovis canadensis bighorn sheep	19	90.5	40.6	49.9	2240.10	1004.95	1235.15	44.86
Mainland 1998b *SEM x 640*		0.18 x 0.24mm (0.0432mm^2)						
Grazing sheep	10	32.0	26.0	7.0	740.74	601.85	162.04	78.79
Grassy hay-fed sheep	10	43.0	33.0	10.0	995.37	763.89	231.48	76.74
Leafy hay-fed sheep	*	70.0	50.0	20.0	1620.37	1157.41	462.96	71.43
Rivals & Deniaux 2003; 2005 *SEM x 500*		0.245 x 0.165mm (0.0404mm^2)						
Grazers								
Ovis ammon antiqua Occupation level Fs	17	58.7	1.1	57.6	1452.97	27.23	1425.74	1.87
Ovis ammon antiqua Occupation level Fb	6	59.2	1.8	57.4	1465.35	44.55	1420.79	3.04
Browsers								
Capra caucasia	8	not given			1435.00	494	941	59.81
Rupricapra pyrenaica	5				2065.00	761	1304	60.18
Modern Anatolian sheep *SEM x 500*		0.245 x 0.165mm (0.0404mm2)						
Spring/summer pasture	3	126	81.33	44.67	3118.81	2013.12	1105.69	64.55
Mid-summer pasture	4	152.75	49	103.75	3780.94	1212.87	2568.07	32.08
Late summer pasture	2	138.5	38	100.5	3428.22	940.59	2487.62	27.44
Autumn pasture	2	95	22.5	72.5	2351.49	556.93	1794.55	23.7
Cereal stubble	1	96	27	69	2376.24	668.32	1707.92	28.1
Bayram feed	3	129	54	75	3193.07	1336.63	1856.44	41.86
Some commercial pellets	1	89	29	60	2202.97	717.82	1485.15	32.58

Appendix 23
Summary of published dental microwear data in modern ungulates with known diets

Sample	All features	Pit %	Pits									Striations								
			Number	Round				Oval				Number	Broad				Narrow			
				Number	Length	Breadth	%	Number	Length	Breadth	%		Number	Length	Breadth	%	Number	Length	Breadth	%
66	128	30.5	39	24	8.9	6.0	61.5	15	13.7	5.0	38.5	89	31	12.7	2.0	34.8	58	30.5	1.3	65.2
65	104	43.3	45	30	10.8	7.4	66.7	15	14.7	5.4	33.3	59	21	15.9	2.4	35.6	38	31.0	1.3	64.4
50	195	25.1	49	33	9.8	6.4	67.3	16	17.3	6.6	32.7	146	43	14.9	2.0	29.5	103	24.5	1.2	70.5
47	98	12.2	12	7	5.4	4.2	58.3	5	8.2	3.3	41.7	85	9	16.1	2.3	10.6	76	29.8	1.1	89.4
64	287	15.0	43	28	8.6	6.1	65.1	15	8.8	3.5	34.9	244	32	11.6	1.8	13.1	212	24.9	0.9	86.9
10	103	27.2	28	14	12.4	8.9	50.0	14	20.5	7.3	50.0	75	13	12.9	1.8	17.3	62	35.3	1.4	82.7
53	219	20.1	44	25	8.2	5.5	56.8	19	15.4	5.5	43.2	175	13	15.8	2.2	7.4	162	32.8	1.4	92.6
52	198	32.8	65	33	11.4	7.8	50.8	32	14.1	4.9	49.2	135	34	17.2	2.6	25.2	99	30.1	1.3	74.8
51	167	31.7	53	36	5.9	3.8	67.9	17	9.0	3.6	32.1	114	17	14.6	2.3	14.9	97	29.4	1.2	85.1
8	172	18.6	32	23	8.2	6.0	71.9	9	13.5	5.3	28.1	140	24	13.2	1.8	17.1	116	29.1	1.2	82.9
54	258	17.4	45	33	7.6	5.6	73.3	12	15.2	6.0	26.7	213	30	16.0	2.2	14.1	183	34.9	1.2	85.9
55	285	34.7	99	59	6.9	5.0	59.6	40	12.8	4.5	40.4	186	41	15.3	2.3	22.0	145	24.7	1.1	78.0
45	176	25.0	44	28	13.4	9.3	63.6	16	11.6	4.3	36.4	132	9	17.1	2.7	6.8	123	14.5	1.3	93.2
7	116	60.3	70	46	7.9	5.3	65.7	24	11.9	4.2	34.3	47	30	17.3	2.9	63.8	16	25.8	1.5	36.2
4	184	16.3	30	19	11.3	8.4	63.3	11	10.0	3.6	36.7	154	38	14.2	2.1	24.7	116	23.5	1.2	75.3
3	75	33.3	25	15	7.7	5.6	60.0	10	10.8	4.4	40.0	50	12	19.7	2.8	24.0	38	29.9	1.4	76.0
2	68	45.6	31	24	11.4	8.1	77.4	7	14.2	5.3	22.6	37	8	14.5	2.9	21.6	29	22.0	1.0	78.4
1	114	32.5	37	29	7.4	5.7	78.4	7	16.3	6.0	21.6	77	13	9.5	1.3	16.9	64	19.8	1.2	83.1
6	101	30.7	31	28	6.7	5.2	90.3	3	11.5	5.2	9.7	70	13	11.2	1.7	18.6	57	29.0	1.2	81.4
15	101	15.8	16	8	6.6	4.4	50.0	8	15.1	5.4	50.0	85	23	16.7	2.3	27.1	62	32.8	1.4	72.9
13	220	10.0	22	12	5.7	4.5	54.5	10	9.3	3.5	45.5	198	51	11.4	1.7	25.8	147	29.4	1.3	74.2
14	505	33.9	171	48	5.1	3.3	28.1	123	7.4	2.5	71.9	334	223	12.7	2.0	66.8	111	24.8	1.5	33.2
39	81	50.6	41	32	10.1	7.1	78.0	9	19.5	7.0	22.0	40	8	12.6	1.6	20.0	32	20.2	1.2	80.0
38	68	35.3	24	14	9.0	6.0	58.3	10	10.1	3.8	41.7	44	14	11.2	1.7	31.8	30	27.4	1.2	68.2
76	101	27.7	28	19	7.0	5.1	67.9	9	13.4	4.9	32.1	73	17	14.7	2.0	23.3	56	25.6	1.2	76.7
72	126	42.1	53	36	5.2	3.7	67.9	17	7.8	3.0	32.1	73	32	12.5	1.7	43.8	41	25.4	1.4	56.2
71	160	26.9	43	35	7.6	5.7	81.4	8	13.2	4.2	18.6	117	15	15.4	2.8	12.8	102	36.9	1.4	87.2
30	267	9.0	24	12	5.0	3.6	50.0	12	8.2	3.1	50.0	243	48	13.2	1.8	19.8	195	25.1	1.1	80.2
75	134	10.4	14	13	6.5	5.1	92.9	1	9.9	4.7	7.1	120	10	17.9	2.6	8.3	110	36.8	1.2	91.7
74	136	28.7	39	18	5.5	3.8	46.2	21	9.7	3.6	53.8	97	26	12.2	1.8	26.8	71	28.3	1.2	73.2
73	240	30.0	72	46	5.9	4.6	63.9	26	8.6	3.2	36.1	167	37	13.5	2.2	22.2	130	24.1	1.1	77.8
35	220	33.2	73	54	5.6	4.1	74.0	19	9.1	3.3	26.0	145	47	14.2	2.1	32.4	98	24.8	1.3	67.6
34	110	30.0	33	11	10.0	6.0	33.3	22	11.1	4.1	66.7	77	21	14.2	2.5	27.3	56	27.0	1.1	72.7
37	173	28.9	50	38	6.4	4.4	76.0	12	8.1	3.1	24.0	122	25	14.3	1.9	20.5	97	27.4	1.4	79.5
36	24	29.2	7	1	8.9	6.5	14.3	6	13.0	5.2	85.7	17	13	13.2	2.1	76.5	4	46.0	2.5	23.5
16	266	28.6	76	43	5.1	3.6	56.6	33	8.6	3.2	43.4	188	67	12.9	1.9	35.6	121	29.0	1.3	64.4
41	97	53.6	52	25	9.1	6.5	48.1	27	13.3	4.8	51.9	45	26	18.6	3.0	57.8	19	23.4	1.6	42.2
40	129	51.9	67	43	9.1	6.6	64.2	24	11.1	4.0	35.8	62	22	12.5	1.7	35.5	40	19.9	1.0	64.5
69	84	25.0	21	12	4.9	3.9	57.1	9	7.8	3.3	42.9	61	6	11.6	1.9	9.8	55	21.7	0.9	90.2
20	45	24.4	11	7	10.9	8.3	63.6	4	17.2	5.4	36.4	34	10	20.2	3.2	29.4	24	45.7	2.1	70.6
19	135	14.1	19	9	9.6	7.1	47.4	10	13.7	4.6	52.6	116	26	13.9	2.1	22.4	90	26.2	1.2	77.6
18	100	35.0	35	22	8.5	5.9	62.9	13	11.5	4.2	37.1	65	15	15.6	2.0	23.1	50	40.9	1.6	76.9
25	221	37.1	82	45	7.6	5.4	54.9	37	11.8	4.1	45.1	139	55	12.0	2.0	39.6	84	24.8	1.3	60.4
24	170	24.1	41	30	9.1	6.7	73.2	11	13.7	5.1	26.8	129	24	15.9	2.1	18.6	105	30.9	1.4	81.4
23	223	29.1	65	35	6.7	4.9	53.8	30	9.6	3.4	46.2	157	48	13.3	2.0	30.6	109	22.4	1.1	69.4
22	90	34.4	31	25	13.1	9.6	80.6	6	18.9	7.7	19.4	59	10	23.3	2.8	16.9	49	33.2	1.7	83.1
21	237	19.4	46	28	9.1	6.7	60.9	18	9.4	3.5	39.1	191	45	14.6	2.2	23.6	146	22.6	1.1	76.4
70	340	15.0	51	32	6.2	4.3	62.7	19	12.5	4.5	37.3	289	54	13.6	1.9	18.7	235	25.0	1.1	81.3
42	101	35.6	36	22	11.8	8.3	61.1	14	14.3	5.5	38.9	65	15	12.7	1.8	23.1	50	27.7	1.3	76.9
61	369	20.3	75	46	5.9	4.2	61.3	29	8.8	3.3	38.7	293	45	12.5	1.9	15.4	248	28.7	1.0	84.6
63	111	26.1	29	21	6.4	4.4	72.4	8	18.7	7.2	27.6	82	9	15.1	2.1	11.0	73	21.5	0.8	89.0
62	49	55.1	27	15	7.5	4.8	55.6	12	12.4	5.0	44.4	22	4	11.9	1.9	18.2	18	40.2	1.1	81.8
56	253	19.0	48	30	6.4	4.6	62.5	18	11.4	4.0	37.5	204	41	12.8	1.9	20.1	163	27.7	0.9	79.9
58	196	46.9	92	46	5.3	3.8	50.0	46	7.9	2.7	50.0	104	32	10.9	1.6	30.8	72	22.8	1.0	69.2
68	164	25.0	41	28	9.1	6.4	68.3	13	14.1	5.2	31.7	123	21	13.5	1.9	17.1	102	25.5	1.1	82.9
57	264	28.0	74	42	7.4	5.3	56.8	32	9.6	3.6	43.2	190	50	15.3	2.3	26.3	140	24.9	1.1	73.7
60	70	57.1	40	24	7.3	5.3	60.0	16	5.8	2.2	40.0	30	10	9.5	1.4	33.3	20	20.7	0.8	66.7
78	58	31.0	18	13	8.5	6.1	72.2	5	12.9	4.9	27.8	40	35	22.6	3.9	87.5	35	41.5	1.8	87.5
77	237	29.5	70	41	7.1	5.5	58.6	29	12.3	4.4	41.4	167	17	26.4	4.2	10.2	150	34.4	1.1	89.8
59	93	24.7	23	14	6.4	4.9	60.9	9	13.6	5.2	39.1	70	7	18.0	2.8	10.0	63	37.6	1.1	90.0
33	203	22.2	45	28	5.6	3.9	62.2	17	8.1	3.0	37.8	158	39	13.2	1.8	24.7	119	28.0	1.2	75.3
32	186	17.7	33	18	7.3	5.2	54.5	16	9.5	3.6	45.5	152	44	13.1	2.0	28.9	108	25.3	1.3	71.1
9	134	35.1	47	20	7.3	4.9	42.6	27	15.7	6.1	57.4	86	22	17.7	3.3	25.6	64	21.7	1.1	74.4
12	102	63.7	65	32	8.1	5.6	49.2	33	9.3	3.4	50.8	37	4	12.2	2.1	10.8	33	22.9	1.2	89.2
28	95	86.3	82	59	6.4	4.4	72.0	23	11.4	4.7	28.0	13	8	11.4	2.0	61.5	5	15.9	1.0	38.5
27	77	63.6	49	26	7.6	4.8	53.1	23	10.6	3.9	46.9	28	13	17.5	2.7	46.4	15	25.4	1.2	53.6
26	105	23.8	25	4	17.4	11.6	16.0	21	20.7	6.8	84.0	80	21	14.9	2.3	26.3	59	30.5	1.7	73.8
31	230	18.3	42	21	8.3	5.8	50.0	21	9.2	3.3	50.0	188	69	12.7	1.9	36.7	119	22.8	1.2	63.3
29	65	18.5	12	4	11.1	6.6	33.3	8	16.0	5.5	66.7	53	6	24.7	3.5	11.3	47	41.2	2.0	88.7
67	54	51.9	28	21	7.7	5.6	75.0	7	10.5	4.6	25.0	25	2	20.1	2.6	8.0	23	51.5	1.7	92.0
44	129	31.0	40	28	8.2	5.4	70.0	12	9.6	3.4	30.0	89	14	13.2	1.9	15.7	75	24.6	1.0	84.3
43	66	30.3	20	12	11.4	8.4	60.0	8	13.1	4.7	40.0	46	16	15.9	2.4	34.8	30	35.3	1.3	65.2

Appendix 24
Dental microwear results for all archaeological tooth specimens

Çatalhöyük groups tested		*Feature category*	*Mean*	*Median*	*Standard Deviation*	*Standard Error*
Whole assemblage		Total	156.42	131.50	86.32	10.17
		Pit N°.	44.31	41.00	25.50	3.01
		Round pit N°.	26.42	25.50	13.34	1.57
		Oval pit N°.	17.89	15.00	15.72	1.85
		Striation N°.	111.94	89.00	71.02	8.37
		Narrow striation N°.	86.64	72.50	54.72	6.45
		Broad striation N°.	27.68	21.50	28.29	3.33
Chronological Phases all specimens/ more secure specimens	6	Total features	120.5/143.14	103.5/134	57.95/67/26	16.73/25.42
	5		187.25/187.25	180/180	106.45/106.46	30.73/30.73
	4		136.8/136.93	129/114.5	75.12/77.96	19.39/20/84
	3		149.36/135.11	134/126	65.80/58.65	19.84/19/55
	2		166/183.14	115/116	129.01/152.31	40.8/57.57
	1		184.5/176.2	183.5/183.5	68.59/67.2	19.8/21.25
	6	Pit percentage	38.53/29.49	30.66/30.3	22.55/11.92	6.51/4.5
	5		31.88/31.88	27.08/27.08	14/14	4.04/4.04
	4		31.04/32.28	29.15/29.16	10.62/9.88	2.74/2.64
	3		29.44/32	30/30	12.02/10.96	3.63/3.66
	2		30.34/33.13	31.58/33.33	14.94/16.91	4.72/6.39
	1		25.73/24.22	26.16/22.61	9.29/9.48	2.68/3
	6	Round pit %	53.16/59.19	53.8/60	16.94/11.25	4.89/4.25
	5		60.85/60.85	60.99/60.99	5.75/5.75	1.66/1.66
	4		59.05/59.89	60.87/61.86	15.83/16.08	4.09/4.3
	3		64.89/64.71	67.86/67.86	17.15/17.49	5.17/5.83
	2		63.14/61.01	63.48/63.33	17.22/16.96	5.45/6.41
	1		62.44/62.18	63.33/63.33	7.6/8.14	2.19/2.57
	6	Narrow striation %	72.44/75.08	74.08/74.42	15.75/10.2	4.55/3.9
	5		80.5/80.5	81.57/81.57	7.71/7.71	2.22/2.22
	4		69.84/69.29	76.44/73.51	17.6/18.13	4.54/4.84
	3		75.6/73.79	76.71/73.2	9.75/9.78	2.94/3.26
	2		70.4/65.21	75.67/75.32	19.71/21.06	6.23/7.96
	1		79.86/79.52	82.76/82.76	9.31/10.12	2.69/3.2
Spatial areas	South Area	Total features	168.53	164	78.13	11.92
	Other Areas		138.5	102	95.8	17.79
	South Area	Pit percentage	29.34	28.7	12.13	1.85
	Other Areas		33.98	29.17	17.14	3.18
	South Area	Round pit %	62.93	62.5	10.58	1.61
	Other Areas		56.64	56.58	17.82	3.31
	South Area	Narrow striation %	77.8	77.8	10.79	1.65
	Other Areas		70.05	74.24	17.44	3.24
Building types	Long-lived sequence	Total features	169.9	136	92.8	21.3
	Other house midden		159.3	129	114	26.86
	Long-lived sequence	Pit percentage	30.01	28.03	12.66	2.9
	Other house midden		30.6	29.73	13.77	3.25
	Long-lived sequence	Round pit %	62.93	61.33	10	2.29
	Other house midden		58.53	60	16.64	3.92
	Long-lived sequence	Narrow striation %	78.95	79.9	9.24	2.12
	Other house midden		70.18	75.66	19.16	4.51

Appendix 25
Descriptive statistics relating to all box-plots (Figs. 11.14-11.17) *of dental microwear in Çatalhöyük specimens*

Oxygen isotope evidence			*Dental microwear evidence*			
			Grass-rich diets		*Soft dicotyledonous diet*	
Sample (=less secure)*	*Birth*	*Movement in first year*	*Dirty grass*	*Clean grass*	*Clean weeds or legume by-products*	*Dirty weeds, grass shoots etc.*
43	May	Plain,fan, sand-ridges, terraces		x		
44	May	Plain,fan, sand-ridges, terraces		x		
67	April	Movement to higher hills or karstic spring			x	
29*	May	Plain,fan, sand-ridges, terraces		x		
31	May	Plain,fan, sand-ridges, terraces	x			
26	April	Plain,fan, sand-ridges, terraces		x		
27	May	Plain,fan, sand-ridges, terraces			x	
28*	March	Plain,fan, sand-ridges, terraces			xx	
12	April	Plain,fan, sand-ridges, terraces			x	
9	May	Plain,fan, sand-ridges, terraces		x		
32	May	Shaded valleys in terraces, lower hills	x			
33			x			
59	?	Shaded valleys in terraces, lower hills		x		
77			x			
78				x		
60	?	Movement to higher hills or karstic spring			x	
57			x			
68			x			
58	June	Plain,fan, sand-ridges, terraces				xx
56	May	Plain,fan, sand-ridges, terraces	x			
62	April	Plain,fan, sand-ridges, terraces			x	
63				x		
61	May	Plain,fan, sand-ridges, terraces	xx			
42	May	Plain,fan, sand-ridges, terraces		x		
70	?	Shaded valleys in terraces, lower hills	x			
21	April	Plain,fan, sand-ridges, terraces		x		
22	May	Plain,fan, sand-ridges, terraces			x	
23	?	Movement to higher hills or karstic spring	x			
24	May	Plain,fan, sand-ridges, terraces	x			
25			x			
18*	?	Plain,fan, sand-ridges, terraces		x		
19*				x		
20	June	Plain,fan, sand-ridges, terraces		x		
69	?	Movement to higher hills or karstic spring		x		
40	May	Plain,fan, sand-ridges, terraces			x	
41	April	Plain,fan, sand-ridges, terraces			x	
16*			x			
36	May	Plain,fan, sand-ridges, terraces		x		
37	June	Plain,fan, sand-ridges, terraces	x			

Appendix 26
Summary of all evidence interpretation for each Çatalhöyük sheep

Oxygen isotope evidence			*Dental microwear evidence*			
			Grass-rich diets		*Soft dicotyledonous diet*	
Sample (=less secure)*	*Birth*	*Movement in first year*	*Dirty grass*	*Clean grass*	*Clean weeds or legume by-products*	*Dirty weeds, grass shoots etc.*
34	May	Plain,fan, sand-ridges, terraces		x		
35*	March	Plain,fan, sand-ridges, terraces	x			
73	May	Plain,fan, sand-ridges, terraces	x			
74	March	Movement to higher hills or karstic spring		x		
75	?	Shaded valleys in terraces, lower hills		x		
30*	?	Shaded valleys in terraces, lower hills	x			
71	May	Plain,fan, sand-ridges, terraces	x			
72					x	
76				x		
38*	May	Plain,fan, sand-ridges, terraces		x		
39	May	Plain,fan, sand-ridges, terraces			x	
14	May	Movement to higher hills or karstic spring	xx			
13	May	Movement to higher hills or karstic spring	x			
15			x			
6			x			
1	March	Plain,fan, sand-ridges, terraces	x			
2	March	Plain,fan, sand-ridges, terraces			x	
3	March	Plain,fan, sand-ridges, terraces		x		
4	April	Plain,fan, sand-ridges, terraces	x			
7	April	Plain,fan, sand-ridges, terraces			x	
45	May	Plain,fan, sand-ridges, terraces	x			
55			x			
54	April	Plain,fan, sand-ridges, terraces	x			
8	June	Plain,fan, sand-ridges, terraces	x			
51	May	Plain,fan, sand-ridges, terraces	x			
52*	April	Plain,fan, sand-ridges, terraces	x			
53*	June	Plain,fan, sand-ridges, terraces	x			
10	March	Plain,fan, sand-ridges, terraces		x		
64	May	Plain,fan, sand-ridges, terraces	x			
47	April	Plain,fan, sand-ridges, terraces	x			
50	May	Plain,fan, sand-ridges, terraces	x			
65	May	Shaded valleys in terraces, lower hills			x	
66	March	Plain,fan, sand-ridges, terraces	x			

Appendix 26 cont.